MITT ROMNEY
GOVERNOR

KERRY HEALEY
LIEUTENANT GOVERNOR

JOHN COGLIANO
SECRETARY

THE COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF TRANSPORTATION

EOT

August 10, 2005

Mr. Robert Golledge
Commissioner
Department of Environmental Protection
One Winter Street
Boston, MA 02108

Dear Commissioner Golledge:

I am writing to submit the Executive Office of Transportation's (EOT) formal recommendation to change the Commonwealth's State Implementation Plan (SIP) with respect to the three projects that have been the subject of recent public hearings and MPO consultation.

The Massachusetts Bay Transportation Authority's (MBTA) evaluation of expansion projects in the 2003 Program for Mass Transportation (PMT) raised concerns about the benefits associated with the three remaining SIP commitments-Arborway Restoration, Red Line-Blue Line Connector, and Green Line Service to Medford Hillside.

Over the last several months, EOT has analyzed these commitments and the high priority expansion projects from the PMT using the adopted statewide criteria. This evaluation included new travel demand modeling information, which replaced earlier forecasting performed for the PMT. As you know, the intent of this reevaluation was to ensure that the Commonwealth invests in the best transportation projects, which also meet the requirements of the SIP.

From this reevaluation process, EOT recommends that the Green Line extension remain as a SIP commitment, and in fact should be expanded to include service to the West Medford area and Union Square using existing rail right-of-ways. EOT also proposes Fairmount Line Improvements/Stations Expansion Project and 1,000 additional parking spaces in the Boston Region MPO as additional transit projects to be implemented under the SIP commitment instead of the Red Line-Blue Line Connector and Arborway restoration.

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This recommendation is based on the objective criteria ratings, as well as, other factors such as air quality targets, project readiness, and geographical equity. Both the Green Line Beyond Lechmere and Fairmount Projects score strongly in the areas of environmental justice and economic and land use impacts. This recommendation meets the air quality budgets of the three outstanding commitments and the additional ten percent improvements required by your department. From our analysis, the expanded Green Line option (now called Green Line Beyond Lechmere) alone meets the total air quality budget needed for the SIP.

Public outreach has been a major element of this SIP reconsideration process to date and, as you know, will continue to be a critical component in our next steps to formalize funding and implementation of the revised transit commitments. Last month we concluded our consultation phase with the Boston Region MPO, a phase that included public meetings and extensive review and discussion of the analyses upon which the SIP change recommendations are based.

Public support has been strong for EOT's recommendation to include the Green Line Beyond Lechmere in the SIP, and the Boston Region MPO was also universally supportive of this project. Strong support also exists for the Fairmount Line Improvements Project by both the general public and the MPO.

Some support has been expressed for the Red Line-Blue Line Connector. The possibility of combining this project with the proposed extension of Blue Line service to Lynn was raised during our outreach. EOT will continue to review this project as it is considered in future planning processes.

In terms of the Arborway restoration project, virtually no MPO member spoke in favor of keeping this project as a legal commitment. Concerns included limited right-of-way in the Arborway corridor and poor access for public safety vehicles. However, support for Arborway restoration does still exist from some residents in this corridor, although other residents just as strongly oppose it.

The feedback from the public confirms our belief that the recommended changes to the SIP will meet air quality requirements with the best transportation projects in the region. EOT supports clear timelines as a regulatory element for the delivery of the recommended projects, even if schedule modifications are necessary from time to time. EOT fully understands that completed projects are the goal. If this substitution does not lead to built projects, this process will not accomplish the ends that we seek.

EOT would suggest that the dates for completion of the projects be as follows:

- 1,000 Commuter rail parking spaces in the Boston region, meaning the 101 cities and towns within the Boston MPO, in addition to those spaces already developed as a result of the original 310 CMR 7.36 –2011;
- Fairmont Line Improvements/Stations Expansion—2011
- Enhanced Green Line Beyond Lechmere— 2014.

To substitute EOT's recommended changes to the SIP, I am offering EOT's suggestions on how that could best be accomplished beyond the specific project changes described above.

EOT's goal for this regulatory change would be that within the overriding requirement for air quality enhancements it is understood that, because transportation needs change over time, any substitution requirements should allow for possible appropriate reevaluation of projects. The requirement should also emphasize the use of accepted transit criteria in reevaluating needs to ensure that the Commonwealth always proceeds with the best possible projects.

EOT would suggest that the language requiring any alternative project to achieve equal or greater emissions reductions be retained, but that the language "in the area where the required project was to be implemented" be modified since it does not necessarily reflect the optimal method of achieving either air quality benefits or transportation benefits.

Today the regulations require that in order for a project to be deemed infeasible, the proponent must prove that implementation is not physically possible due to engineering, environmental or economic considerations. This creates an unrealistic standard. EOT would therefore recommend language that speaks to a project no longer being an appropriate transportation project due to factors including, but not limited to, engineering, environmental, community, or economic impacts, adverse impacts to the existing transit network, and a failure to meet generally accepted cost effectiveness criteria.

EOT does not mean to suggest that future project substitutions should be easy; we expect DEP to retain any requirements on meeting air quality standards and retaining or developing a strong public process for review of substitutions. Let me reiterate that we are committed to these projects going forward.

I therefore formally request that DEP move forward with changes to its SIP regulations and to substitute the Green Line Beyond Lechmere; Fairmount Line Improvements/Stations Expansion; and 1,000 additional parking spaces in the Boston Region MPO for the current commitments of the Arborway Restoration, the Red Line-Blue Line Connector and the Green Line to Medford Hillside.

Attached are matrices of comments offered by MPO members, as well as, those that were received by the MPO in their outreach to the public. I am also attaching a description of the modeling used by the Central Transportation Planning Staff (CTPS), an analysis of the substitutions run through the model, and documentation of how the substitutions meet the objective criteria. If you have additional questions, please do not hesitate to contact me.

Sincerely,

John Cogliano
Secretary

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John Cogliano
MPO Chairman

July 19, 2005

John Cogliano
Secretary
Executive Office of Transportation
Ten Park Plaza
Room 3170
Boston, MA 02116

Dear Secretary Cogliano:

As your designee to the Boston Region Metropolitan Planning Organization (MPO), I am writing to inform you of the outcome of our recent consultation with the MPO on the Executive Office of Transportation's (EOT) proposed changes to the State Implementation Plan (SIP).

The need for this consultation was detailed in Governor Weld's July 9, 1993 letter to the Environmental Protection Agency (EPA), "...the Executive Office of Transportation and Construction (EOTC), as chair of the Metropolitan Planning Organization (MPO), and in consultation with other MPO members, shall be the lead agency in SIP planning for all transportation initiatives." On Thursday, June 30, 2005, after two MPO consultation meetings and an MPO-sponsored public meeting to hear from members of the public, the members of the Boston Region MPO provided EOT with their recommendations on the SIP re-evaluation process and the proposed changes.

The Boston Region MPO was universally supportive of EOT's recommendation to honor the extension of Green Line service as a SIP commitment. Members voiced the importance of serving environmental justice neighborhoods in Somerville, as well as, the strong demand and support for this service. The MPO also is strongly in favor of the proposed substitution of the Fairmount Expansion Project, since it has been a priority of the MPO. The MPO's support is found in both the long range plan and the annual Transportation Improvement Programs (TIP), which have included funds for state-of-good repair work along this line.

In terms of the Arborway Restoration Project, MPO members were equally unified in their lack of support for this project. No member spoke in favor of keeping this project as a legal commitment. Concerns included limited right-of-way in the Arborway corridor; poor access for public safety vehicles, and lack of support by the host community, the City of Boston. The City of Boston and several other members expressed the need for bus improvements along the Arborway corridor, and felt the MPO's study of signal prioritization along this corridor may help.

A cooperative transportation-planning effort of the:

Executive Office of Transportation

City of Boston

City of Everett

City of Newton

City of Salem

Federal Highway Administration (ex officio)

Federal Transit Administration (ex officio)

Massachusetts Bay Transportation Authority

Massachusetts Bay Transportation Authority Advisory Board

Massachusetts Highway Department

Some members voiced support for the Red-Blue Connector because it will serve environmental justice neighborhoods north of Boston. In particular, supportive members felt that this project would improve mobility to important destination such as Massachusetts General Hospital. Some members mentioned the possibility of combining this project with the proposed extension of Blue Line service to Lynn.

In general, members supported increased parking in the Boston region; however, certain members questioned its inclusion as part of the SIP.

This action completes EOT's consultation with the Boston MPO. However, the MPO will need to consider an amendment to its long range plan, if SIP changes are adopted by the Environmental Protection Agency (EPA) and the Department of Environmental Protection (DEP).

Attached are matrices of comments by members and by the public to the MPO. If you have additional questions, please do not hesitate to contact me.

Sincerely,

Dennis A. DiZoglio, Chair
Transportation Planning and
Programming Committee

Enclosure

Name	Affiliation	Comments from Members of the Public
Carrie Schnieder	Conservation Law Foundation	Commitments were made to specific communities, and the original projects are good projects. Questioned where the 1000 parking spaces would be located. Questioned whether West Medford wants the Green Line extension. Fairmount line has few air quality benefits.
John Deacon	Sierra Club	The West Medford extension of the Green Line is overdue and should be under construction now. The analysis conducted on the Arborway is not credible. In terms of cost effectiveness, the Arborway branch should be compared to other Green Line branches. Somerville should get whatever it wants in terms of the Green Line.
Ken Krause	Medford resident, Beyond Lechmere Committee	Supports Green Line to West Medford. The Beyond Lechmere Committee has some concerns about the proposed alignment of the Green Line extension to West Medford. They will hold a public meeting on Monday, June 27. Suggested considering relocating the West Medford commuter rail station to reduce the number of grade crossings. The Green Line will promote job growth in Somerville.
Marvin Martin	Four Corners Action Coalition	Supports Fairmount Line. Will need to increase frequency of Fairmount Line trains to realize air quality benefits. Does not want project to be scrutinized against other neighborhood projects.
Emmanuel Bellegrade	Mattapan CDC	Supports Fairmount Line. The Fairmount Line should be a high priority project.
Natasha Perez	Gravestar, former East Boston resident	Supports Red-Blue Line connector. Says that East Boston is a low-income community with a significant immigrant population and is cut off from the city.
Jim McGinnis	Somerville Transportation Equity Partnership, Beyond Lechmere Committee, Somerville resident	Supports Green Line to Union Square and West Medford. Union Square is an Environmental Justice community, has existing mixed-use development, and has potential for transit-oriented development. Lechmere station can accommodate 50% more trains than the CTPS model projects. West Medford and Union Square extensions of the Green Line could show more benefits if reevaluated.
Ginger Lawrence	Beacon Hill Resident	Supports Red-Blue line connector. Beacon Hill has poor air quality and is ringed by highways. The Red-Blue connection would alleviate traffic congestion. The proposed substitute projects do not benefit Beacon Hill.
Bill Shelton	Mystic View Task Force	Supports Green Line to West Medford and Union Square.
Peter Varga	Union Square Main Streets	Supports Green Line to West Medford and Union Square. Union Square is a heavily burdened urban district, as it handles traffic from I-95, McGrath Highway, major truck routes, and five bus routes.
Wig Zamore	Mystic View Task Force/Somerville Transportation Equity Partnership	Supports Green Line extension to Somerville. The extension will meet the intent of the Clean Air Act and the Ozone SIP. Emissions are greatest in Somerville and Chelsea, and Somerville has the highest vehicle miles traveled/square mile of any community in Massachusetts. Eastern half of Somerville has the most trips and the greatest development opportunities. The community is in unanimous support.
Katjana Ballantyne	Somerville Resident	Supports Green Line extension to Somerville.
Iliana Nilsson	Somerville Resident	Supports Green Line extension to Somerville. Wants clean air.
Alan Moore	Somerville Bike Advisory Committee	Supports Green Line to West Medford and Union Square. The best way to get projects done is to keep with the existing list. Should find other funding for other projects.

Name	Affiliation	Comments from Members of the Public
Robin Chase	Cambridge Resident, ZipCar founder	The evaluation criteria for air quality should include considerations for carbon dioxide, other greenhouse gases, and fossil fuel costs.
Vincent Bono	Roslindale Resident	Has concerns about scoring system used to evaluate projects. A private consulting firm found two arithmetic errors in analysis report. In terms of the Red-Blue line connector, overall ridership on the Silver Line should be incorporated. Methods for evaluating for modal connections on the Green Line extension to West Medford should be revisited as well.
Lori Segall	Somerville Resident	Supports Green Line extension to West Medford and Union Square. Climate change considerations should be included in analysis. Vehicle Miles Traveled is the most important measurement to evaluate projects.
Jane Sauer	Somerville Resident	Supports Green Line extension to Somerville. Other commitments should be honored.
David Dahlbadea	Somerville Resident	Supports Green Line extension to West Medford and Union Square. Local, not regional air quality, should be considered in terms of Environmental Justice. The requirements of the Massachusetts Environmental Justice regulations should be incorporated. Air and water quality should be evaluated together.
Srdjan Nedeljkovti	Arborway Resident	Supports Arborway. Air quality determinations and other data for the Arborway are inaccurate and flawed. There are 40 reasons why the data is flawed. The modeling does not account for transit-dependent riders. The data does not account for the desire for users to ride trains over buses. Data used is from 1990 and is outdated. The data excludes walking trips. The restoration of the Green Line on the Arborway will generate 6000 new riders, not 600 as predicted. The data should not be accepted.
Fred Salvucci	Self	Supports all proposed projects. Signed commitment with the intention of completing the projects by 2000. It is unfair to compare committed projects to new projects. Air quality was not the primary basis for choosing committed projects. If the committed projects did not go forward, the Commonwealth was required to replace those projects with projects with the same or more air quality benefits in the same neighborhood. The original agreement should be honored.
Karen Wepsic	Arborway Committee	Supports Fairmount Line and Green Line Extension to West Medford. Questioned current ridership on #39 bus. The 1000 parking spaces should not be included in the commitment, as they will encourage sprawl. The Silver Line Phase 3 will not connect Dudley Square to South Station on all trips.
Jeff Kurland	Arborway Committee	EOT and MBTA should not delay the Arborway project. The project has missed four funding cycles and intentional mistakes have been made to sabotage the project.
Shelly Goehring	Four Corners Main Street	Supports Fairmount Line. Residents near the Fairmount Line have no other options.
Nicole Flint	Project RIGHT	Supports Fairmount Line. Fairmount service should be frequent. Station locations should be reconsidered.
Fred Berman	Somerville Resident	Supports Green Line extension to Somerville. Projects not recommended should not be abandoned. A connection between Tufts University and Porter Square should be considered.
Ellin Reisner	Somerville Transportation Equity Partnership	Supports Green Line extension to West Medford and Union Square. There are great development opportunities in Union Square.

Name	Affiliation	Comments from Members of the Public
Peter Nersesian	Resident	Supports Arborway. Land use impacts should be considered on Arborway, as the Arborway needs significant transit infrastructure to stimulate development. The Red-Blue Line connection would be supported by the Blue Line extension to Lynn.
Franco Marzo	Dorchester Resident	Supports Fairmount Line. New equipment and upgrades to stations will be needed. Service should be seven days a week.
George Brady	Somerville Resident	Should be planning for the next 100+ years. Important to take a long-term view.
Ade Baptista	Somerville Resident	Consider extending transit line into affordable areas and work to keep them affordable. Should provide multiple connections, line extending the Green Line in West Medford to Porter Square.

Written Comments Regarding State Implementation Plan Transit Commitments

Name	Affiliation	Comments from Members of the Public
Mara Vorhees	Somerville Resident	Supports Green Line extension to West Medford. The Green Line will help revitalize Union Square. A commuter rail stop in Union Square is a temporary solution, but the Green Line should ultimately be extended.
Todd Van Hoosear	Somerville Resident	Supports Green Line extension through Somerville. The Somerville Community Path, connecting Somerville to the Minuteman Bike Trail, should be incorporated into the Green Line extension.
Mark Pener	Brookline Resident	Supports Green Line extension through Somerville.
Fred Salvucci	Self	Existing SIP commitments should be upheld. The Red-Blue Line connection should be expedited. Strengthen 2000 ACO to mitigate risk of congesting the Big Dig. SIP commitment projects make sense. The methodology used to select projects is inappropriate for the SIP commitments.
Thomas G. Ambrosino	Mayor of Revere	Supports Red-Blue Line connector. North Shore has been adversely affected by Big Dig construction. Connection from Revere to MGH is important.
Justin Klekota	Somerville Resident	Supports Green Line extension to West Medford.
Ellin Reisner	Somerville Transportation Equity Partnership	Supports Green Line extension through Somerville and to Union Square.
	Fairmount Indigo Line Coalition	Supports Fairmount Line, which will provide rapid transit service to a transit-dependent community in Boston.
Kelly Begg Lawrence	Cambridge Resident	Supports Red-Blue Line connector. Important to strengthen the hub of the transit system before extending to outlying areas
Andrea Yakovakis	Somerville Resident	Supports Green Line extension to Union Square and West Medford.
Amy Troutman	Somerville Resident	Supports Green Line extension through Somerville.
Sally Zeckhauser	Harvard University	Supports the Urban Ring project. Transit connections are needed between life sciences institutions.
Nicole Flynt	Project RIGHT	Supports Fairmount Line with a station at Columbia Road.
Thomas P. Glynn	COO, Partners Healthcare	Supports Red-Blue Line connector, which will fill excess capacity on the Blue Line. Also provides connections to MGH and facility in Revere. Supports Green Line extension through Somerville. Will improve air quality and connections to Tufts University Medical School. ACO for Arborway should be upheld, whether or not light rail is feasible.
David Ragucci	Mayor of Everett	Supports replacement projects as recommended by EOT.
Larissa V. Brown, David J. Harris	Boston Society of Architects-Civic Initiative for Smart Growth, Fair Housing Center of Greater Boston	Proposed revisions to SIP do not benefit Jamaica Plain, East Boston, Revere, Beacon Hill, or Cambridge. The geographic equity of the original projects is not reflected in the recommendation. Original commitments should be honored.
Lowell L. Richards III	Massachusetts Port Authority	Supports objective criteria used to evaluate transit projects and public process. Supports recommendation to not include Red-Blue Line connector in SIP commitments. Supports Green Line extension to West Medford and Union Square.
	Steering Committee of On the Move: Greater Boston Transportation Justice Coalition	Supports Fairmount Line, including five new stations. Supports Green Line extension to West Medford and Union Square. EOT needs to show equal or greater air quality benefits in Arborway corridor and Red-Blue Line connector communities before they can be removed from the SIP commitments. 1,000 parking spaces do not benefit communities with current SIP commitments, and should not be included. Timeline for completion of projects must be created.
Jarrett T. Barrios	State Senator, Middlesex, Suffolk, and Essex Counties	Supports Green Line extension to Medford and Union Square. Offers support for securing financing and resources for timely completion of the Green Line extension. Supports Red-Blue Line connector.

Name	Affiliation	Comments
Paul Regan	MBTA Advisory Board	Had difficulty balancing role as member of Environmental Oversight Committee of Central Artery/Tunnel project and interest in the Transportation Improvement Program, Program for Mass Transportation, and the MBTA Budget. In reviewing the commitments and recommendations, one should look at all the transit projects that were required as part of the Central Artery/Tunnel project and the existing investments. The Fairmount Line project was not a commitment, but it deserves to be included in the recommendation. It has public support from the City of Boston and the affected neighborhoods, and serves a transit-dependent, environmental justice neighborhood. The service would provide better commuting options and connectivity within the inner core area. Supports Green Line extension through Somerville with or without the branch to Union Square. Hopes to see Somerville use this opportunity for revitalization along the Washington Street corridor. Struggled with the Red-Blue Line connector. It would be a good project if done in conjunction with the Blue Line extension to Lynn. The extension to Lynn could be partially funded by New Starts, making it not solely a state-funded project. The ridership generated by the extension to Lynn would justify the connection between the Red and Blue Lines. The Arborway project is an inflexible, 1940s solution to the transportation problems in Jamaica Plain. Found no previous examples of a transit authority operating light rail at grade in two-way traffic. The Arborway project is unsupportable from an urban planning perspective. All of the projects, except the Red-Blue Line connector, will place operational burdens on the MBTA. New funding will be needed to pay for the operational costs of the projects. Additional parking is needed and desired just about everywhere. Suggests that additional parking be focused in the inner core. Understands that commitments were made and should be kept, but the transportation system as it exists today and the funding constraints are what needs to be considered today.
Joe Cosgrove	MBTA	The MBTA has been grappling with all the issues related to the legal commitments and potential replacement projects. There are significant implementation problems with the Arborway project, as has been noted in its 20 year process. The EOT recommendation reflects that transportation finance has significantly changed since 1990. The commitments are a commonwealth commitment. The MBTA does not have the resources to pay for them. This brings balance and a dose of reality to the MBTA’s views of the EOT recommendation. An effort was made to select projects that can be implemented soon, so as not to defer the burdens to future administrations. The MBTA is supportive of the EOT recommendations, while acknowledging that additional planning work is necessary. The Fairmount Line project will perform very well in terms of equity and land use. The project will help fill extra capacity on the line. The Green Line extension through Somerville will succeed in terms of land use, regional equity, and mobility. The EOT recommendation is balanced and includes a realistic mix of projects that can be implemented.

Barbara Lucas	Metropolitan Area Planning Council	MAPC has consistently stated that the air quality benefits realized in replacement transit projects for the SIP should be linked to their corridors. This is not achieved with the EOT recommended projects. There must be a problem with the analysis that states the Green Line extension to West Medford and Union Square is greater than 110% of the original commitments combined. The three projects recommended by EOT are good projects. However, the Fairmount Line project does not provide significant air quality benefits in the corridor. Would like to see bus prioritization in the Arborway corridor become part of the SIP transit commitments. The Red-Blue Line connector has suffered from a lack of significant public support, as it is not a corridor project. The connector will reduce congestion in downtown stations, fill excess capacity on the Blue Line, and improve system connectivity at no operational cost to the MBTA. Would like to see it move forward. Disappointed that it is not being included in the recommendation. Pleased to see that the Green Line extension through Somerville is a recommended project. The Fairmount Line is an excellent project, but it should not replace other projects in the SIP transit commitments. The project has been previously supported by the MPO outside of SIP discussions. Additional parking is needed in the inner core as well as the suburban areas. Hopes to see additional parking capacity added in the region, but it should be added because there is a need an not simply as part of the SIP commitments. Deadlines for implementation should be included for each project to be included in the SIP.
Tom Kadzis	City of Boston	Appreciates that the projects selected in 1990 are benefiting from a round of re-analysis. Decisions made now must be sensitive to the communities in which transportation projects were committed. The City of Boston strongly supports the Fairmount Line project. Improvements to public transportation in the Arborway corridor should be aggressively pursued. The South Street and Center Street rights-of-way provide significant physical constraints. Improvements should include roadway reconstruction, bus shelters, and ITS tools such as bus signal prioritization and GPS advanced notification. The City of Boston believes the Red-Blue line connector should be implemented. If the Red-Blue Line connector is not retained in the transit commitments, replacement projects should provide benefits to East Boston. The recommended projects would result in a reduced level of investment in transit in Boston. The City of Boston looks forward to the opportunity to comment on this as a community speaking for its citizens during the Department of Environmental Protection review. The re-evaluation process has been positive.
Steve Olanoff	Regional Transportation Advisory Council	The Regional Transportation Advisory Council will meet on July 13 to discuss the SIP commitments.
David Koses	City of Newton	Mayor Cohen supports the Green Line extension to West Medford as a SIP commitment and supports the recommendation not to move forward with the Arborway project. The Green Line branch to Union Square does not have as high user benefits as the Red-Blue Line connector. The connector is a worthy project and the City of Newton recommends it stay as a SIP commitment.

Mary Pratt	Town of Hopkinton	Deadlines should be set for the completion of all projects. Supports the Green Line to West Medford, as it has strong air quality benefits. Noted that the Red-Blue Line connector has higher user benefits than the Green Line branch to Union Square. Light rail on the Arborway made sense when fewer cars were on the road, but this is a thing of the past. Priority should be given to bus signal prioritization in the Arborway corridor. A study should be funded in the FY 2006 UPWP. The Red-Blue Line connector is a worthy project despite minimal support from the affected communities. Additional parking is needed in the region, but should not be used as a replacement project. In the future, promises should not be made if they will not be kept. Creative funding sources should be sought to pay for necessary transit improvements. Supports the Fairmount Line project, but questions whether it should replace the existing SIP commitments.
Shirin Karanfiloglu	Massachusetts Turnpike Authority	Supports the re-analysis of the SIP transit commitment projects. Air quality is one important aspect, but economic development, quality of life, and urban planning issues are important. The increased utilization of the Fairmount line in the proposed project is an excellent idea. The Green Line extension through Somerville is excellent in terms of economic development, accessibility, air quality, and quality of life. Additional parking capacity should be added to areas where parking lots are often full. The Red-Blue Line connector raises technical questions and it is costly, though it would provide access to Mass General Hospital for employees and patients. Buses might be a good substitute.
Lynn Duncan	City of Salem	There is support on the North Shore for the Blue Line extension to Lynn and the Red-Blue line connector. Mayor Usevich is supportive of the proposed substitutions.
Lowell L. Richards III*	Massachusetts Port Authority	Supports the re-evaluation efforts to provide better air quality benefits than the original commitments. The introduction of Silver Line service to Logan Airport may provide the connection between the Red and Blue Lines that many customers need. It makes sense to replace the Red-Blue Line connector with other projects in the SIP. Supports the Green Line extension to West Medford and Union Square.

*Comment received in writing after the June 30 meeting

TRANSIT CRITERIA FOR SIP RE-EVALUATION PROCESS

The Executive Office of Transportation (EOT), in conjunction with the MPOs, has led the effort to develop statewide criteria for highway and transit projects. Objective criteria will help to ensure that the best projects are selected through a transparent process. The Objective Criteria for transit closely follow the principles established in the 2003 Program for Mass Transportation (PMT), in which the Massachusetts Bay Transportation Authority (MBTA) developed seven categories of performance measures. The following is a summary of the current statewide criteria for transit projects:

Utilization

- User Benefit: This measure captures the direct transportation benefit to existing and new customers due to increased ridership resulting from improvements in access to the system, in average travel speed, in system reliability, and in transfers and connections. Reduction in total travel time can be used as a proxy if data are not sufficient to estimate user cost savings.

Mobility

- Expansion of transit access to geographical areas underserved by transit; to major employment centers underserved by transit; and during time periods poorly served by transit
- System Reliability
- Interconnectivity/Transfers

Cost-Effectiveness

- User Benefit/Annualized Project Cost (Capital + Operating)
- Fare Recovery: Additional Annual Revenue/Annualized Cost

Air Quality

- Total annual tonnage reductions in emissions of volatile organic compounds, nitrogen oxide, and carbon dioxide

Service Quality

- Enhancements to customers' personal safety
- Improvements to station access and/or comfort of vehicles and stations
- Improvements to customer information, including navigational tools

Economic and Land Use Impacts

- Serves an existing urbanized area
- Brownfields and infill
- Populations and employment centers
- Existing land use character
- Transit supportive zoning

Environmental Justice

- Service to minority and low-income
- Rectification of structural and/or operational transportation barriers faced by minority and low-income
- Response to environmental justice issues identified in MPO Regional Transportation Plans
- Burdens and benefits to minority and low-income

Travel Modeling and Other Techniques Used for SIP Project Analysis

Spring 2005

This memorandum describes the modeling and other analytic techniques used in the SIP project analysis. The first section describes general features of the regional model set and each of its steps. The second section describes changes made to the model set in response to FTA guidance received while conducting modeling for the Silver Line III. These changes were carried into the modeling done for the SIP projects. The third section describes how emissions estimates were made, usually using outputs of the travel model set. Finally, the fourth section describes the SUMMIT program that was distributed by FTA and used to calculate user benefits, one of the measures required in the SIP project analysis.

I. TRAVEL DEMAND MODEL

General Description of the Model

The travel model set is based on procedures that have evolved over many years at the Central Transportation Planning Staff (CTPS). The model set is based on the traditional four-step urban transportation planning process of trip generation, trip distribution, mode choice, and trip assignment and is implemented in the EMME/2 software package. This process is employed to estimate daily transit ridership and highway traffic volumes, primarily on the basis of forecasts of study area demography, land use assumptions, and projected highway and transit improvements. The model set simulates travel on the entire eastern Massachusetts transit and highway system.

The Four Steps

In the first step, the total number of trips generated by residents of the CTPS Modeling Area (the 101 MAPC cities and towns that make up the Boston MPO together with 63 communities outside of the Boston MPO) is calculated using demographic and socioeconomic data. Similarly, the number of trips attracted to different types of land use such as employment centers, schools, hospitals, shopping centers etc., is estimated using land use data and trip generation rates obtained from travel surveys. This information is produced at disaggregated geographic areas known as traffic analysis zones (TAZ). All calculations are performed at the TAZ level.

In the second step, the model determines how the trips generated in each TAZ are distributed throughout the region. Trips are distributed based on transit and highway travel times between TAZs and the relative attractiveness of each TAZ which is influenced by the number of jobs available, size of schools, hospitals, shopping centers etc.

Once the total number of trips between TAZs is determined, the mode choice step of the model (step three) allocates the total trips among the available modes of travel. In our case, the available modes of travel are walk, auto (SOV and carpools) and transit (walking to transit and driving to transit). To determine the proportions of each mode, the model takes into account the travel times, number of transfers required, parking availability and costs associated with these options. Other variables such as the auto ownership and household size are also included in the model.

After estimating the number of transit and auto trips for all possible TAZ combinations, the model assigns them to their respective mode of transportation (this is the fourth and final step). Various reports showing the transit ridership on different transit modes (including estimates of passenger boardings on all the existing and proposed transit lines) and traffic volumes on the highway network are produced according to our needs. A schematic representation of the modeling process is shown in Figure 1.

Model Features

The model set uses the best component models, networks and input data available to CTPS at this time. Some of the features of the model set include:

- The model set incorporates motorized and non-motorized trips.
- The model is set up to simulate passenger and highway travel during four time periods of a typical weekday.
- The trip generation, trip distribution and mode choice portions of the model set are well calibrated.
- The model set recognizes the parking lot capacity constraints when assigning park and ride trips but isn't constrained by them.
- The park and ride trips can be reassigned to the highway network for a more realistic highway assignment.
- EMME/2 software used in implementing the model is capable of performing simultaneous multi-class and multi-path and transit highway assignment that is superior to the traditional all-or-nothing assignment.
- The procedure that estimates air quality benefits is sophisticated and well integrated within the main model.

Description of Model Parameters

Modeled Area: The modeled area encompasses 164 cities and towns in Eastern Massachusetts, which includes 101 MAPC region cities and towns, and 63 Communities outside of Boston MPO, as shown in Figure 2. The figure also shows the boundaries of five concentric rings into which the modeled area is divided for model estimation and calibration purposes. These rings will be referred to in subsequent discussions.

Figure 1: The Four Step Demand Modeling Processes

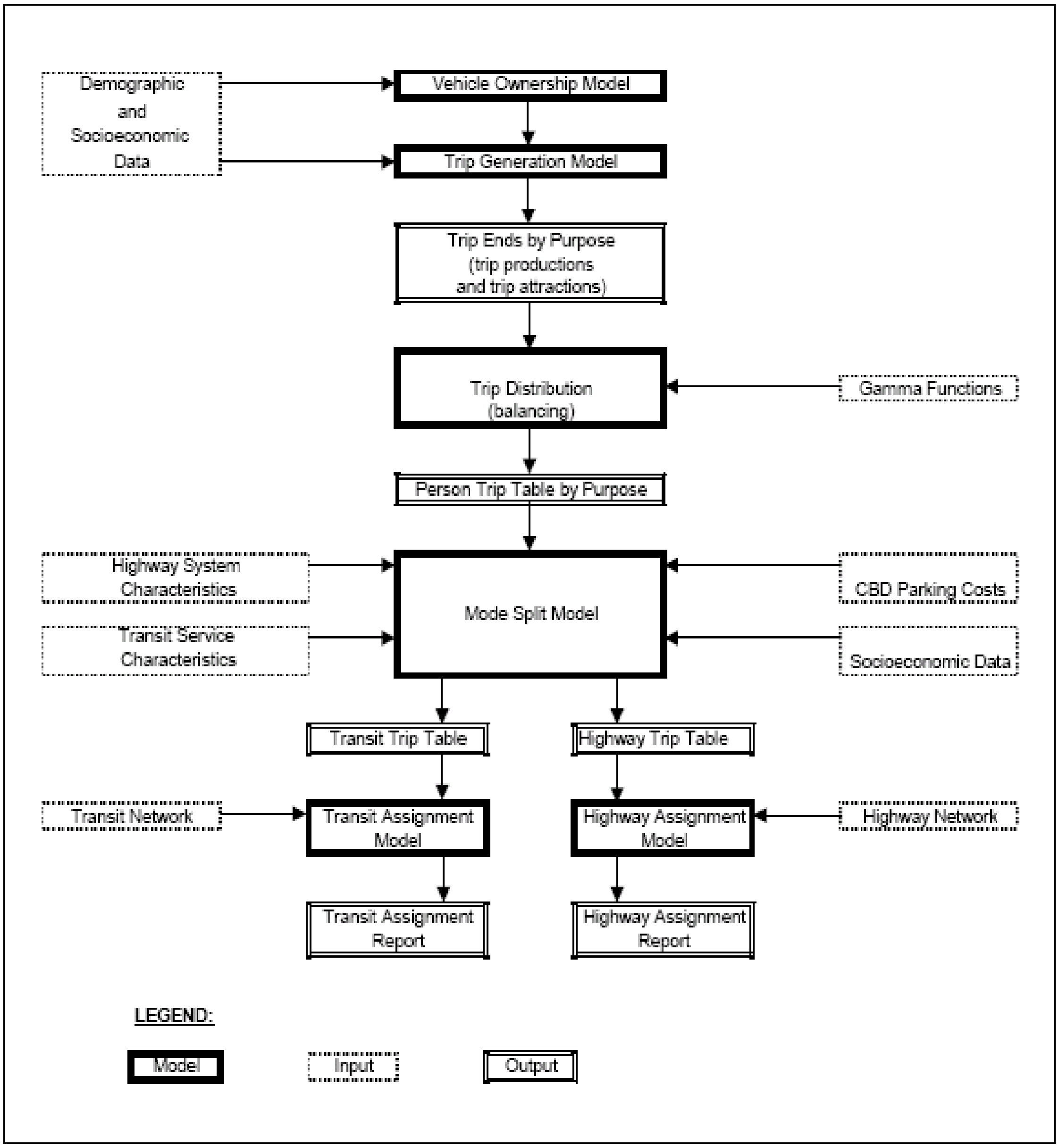
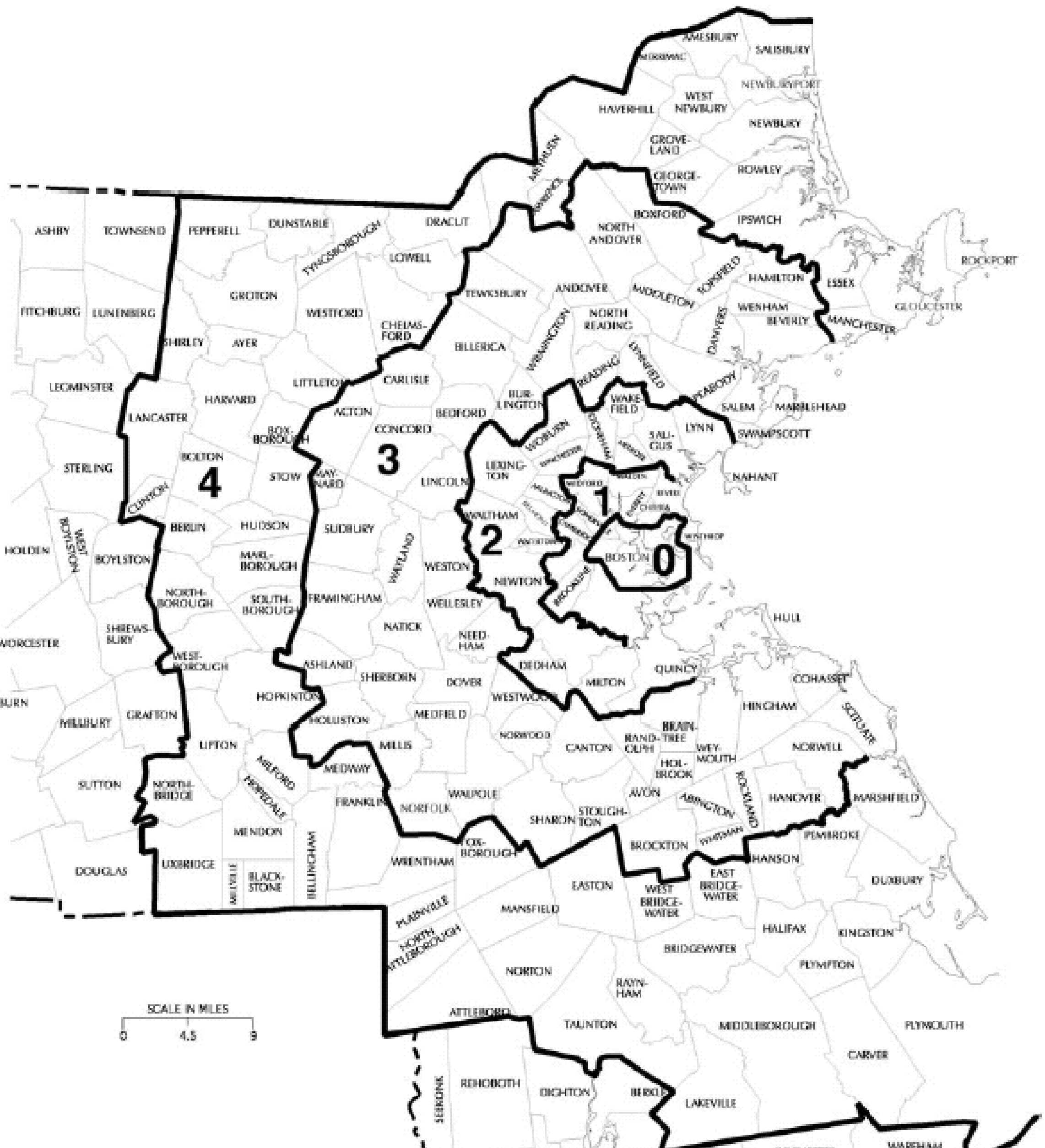


FIGURE 2 CTPS Modeled Area and Ring Boundaries



Zone System: The modeled area is divided into 986 internal Traffic Analysis Zones (TAZs). There are 97 external stations around the periphery of the modeled area that allow for travel between the modeled area and adjacent areas of Massachusetts, New Hampshire and Rhode Island.

Model Inputs: The model inputs include: Population/households, employment, transit level of service, transit fares, highway level of service, highway tolls, and automobile operating costs including parking. This section lists the major data items underlying the model set.

1990 and 2000 U.S. Census: Various files were used in model estimation and calibration processes.

Site-level Employment Database: Employment estimates for 1991 were taken from state-provided sources and a commercial vendor's database purchased by CTPS, and combined into a single, unified regional employment database.

Household Travel Survey: In 1991, CTPS conducted a household travel survey. Then survey took the form of an activity-based travel diary that was filled out for one weekday. Approximately 4,000 households, generating some 39,000-weekday trips were represented in the final database. The data were used to estimate new trip generation, auto ownership, trip distribution and mode choice models.

Transportation Networks: There are two types of networks; transit and highway. Both are integrated in EMME/2. The highway network is comprised of express highways, principal & minor arterials and local roadways. The transit network is comprised of commuter rail lines, rapid transit lines and bus lines (MBTA + Private carriers). The model contains service frequency (i.e. how often trains and buses run), routing, travel time and fares for all lines.

External Cordon Survey: Also in 1991, a survey of automobile travelers bound for the modeled area from adjacent areas was performed. Survey results were used in trip generation and distribution to update estimates of external trips.

Ground Counts: Transit ridership and highway traffic volume data representing 2000 through 2004 conditions were amassed into a database and used to calibrate the travel sub-models.

Analysis Year: Base year is 2004 and the horizon year is 2025 for which the Land Use Scenario is based on Trends Extended.

Highway Network: The regional highway network contains in excess of 40,000 links and 15,000 nodes. It is fairly dense in the study area, although like any modeled network, it does not include some local and collector streets. Each link is coded with the appropriate free-flow speed, number of lanes and lane capacity. Functional class is coded, as are various geographic flags useful for summarizing emissions.

Transit Network: The transit network represents all MBTA bus and rail services in Eastern Massachusetts, as well as private express buses and Boston Harbor ferries. Most-likely travel paths are built through the network, then skimmed and the resulting impedances are input to the trip distribution and mode choice models. After mode choice, transit trip tables by time of day are assigned to the network travel paths.

Time of Day Considerations: In the current version of the travel model set, the mode choice and transit assignment are conducted for four time periods: AM peak period, Midday, PM peak period, and night-time. The trip generation model however, is based on daily trips. The trip distribution model considers two time periods, peak and off-peak periods.

The highway and transit networks are built separately for each time period. Table 1 shows the time intervals associated with each time period. The highway vehicle trips created by the mode choice model are converted from production/attraction format to an origin/destination format prior to network assignment. Transit person trips are also transformed from production/attraction format to origin/destination format, for each time period and assigned to the transit network.

The factors used in dividing the highway person trips into different time periods were obtained from the 1991 Household Travel Survey. The final trip tables created for each time period correspond to observed levels of congestion on the highway system. The results of the four assignments are summed to obtain daily (AWDT) results.

Table 1 – Time Periods for Trip Assignment

Time Period	Highway Vehicle Trips	Transit Person Trips
AM Peak Period	6:00 am - 9:00 am	6:00 am - 9:00 am
Midday	9:00 am - 3:00 pm	9:00 am - 3:00 pm
PM Peak Period	3:00 pm - 6:00 pm	3:00 pm - 6:00 pm
Early/Evening/Night	6:00 pm – 6:00 am	6:00 pm – 6:00 am

Population and Employment Forecasts

Households and employment by type are major inputs to the travel model process: they are the variables upon which trip generation is done. The Metropolitan Area Planning Council (MAPC) using what is called a “Targeted Growth” method developed the forecasts of households and employment for this region independently. In this method, growth is targeted to denser areas with available water and sewer infrastructure with a focus on development around transit stations.

Trip Generation Model

The first step in the CTPS Regional Travel Forecasting Model Set for Eastern Massachusetts is the trip generation model. This model uses socioeconomic characteristics of the region and basic information about regional transportation infrastructure, transportation services, and geography to predict the amounts of travel, which will be produced and attracted to the transportation analysis zones (TAZs) within the Eastern Massachusetts region.

The CTPS trip generation model is composed of the following nine parts and a description of each of these parts is presented thereafter:

- Base year inputs
- Future year inputs
- Estimation of base year input requirements for future years
- Estimation of detailed socioeconomic characteristics
- Estimation of vehicle ownership
- Estimation of trip productions and attractions
- Balancing of trip productions and attractions
- Elimination of Logan trip productions and attractions
- Preparation of files for other components of the regional model set

Base Year Inputs

The base year inputs required for the trip generation model include the following: total households, total population, group quarters population, households by household size, households by income quartile, households by workers per household, households by size, income, and workers per household, population by age, basic employment, retail trade employment, services employment, school employment (K-12 and college), resident workers, dorm population, labor participation rates, land area, Logan person trips, external person trips, attraction and production terminal times, and transit walk access factors . For the base year trip generation applications, data from the 2000 US Census of Population is used where available. Estimates for the year 2000 are generated for those variables that are still based upon 1990 US Census data through application of the forecast year procedures described below.

Future Year Inputs

The future year inputs required for the trip generation model include the following: total households, total population, group quarters population, population by age, basic employment, retail trade employment, services employment, labor participation rates, Logan growth factors, external growth factors, and transit walk access factors. These data are used to estimate the future year levels for the variables listed as base year input requirements following the procedures described below.

Estimation of Base Year Input Requirements for Future Years: Various procedures are used to prepare the trip generation model input data for future years. The variables that are estimated in these procedures include the following: households by household size, households by income quartile, resident workers, households by workers per household, school employment (K-12 and college), dorm population, Logan person trips, external person trips, and attraction and production terminal times.

Household Size: The change in TAZ average household size is implied in the base year inputs and future year forecasts (total population minus group quarters population divided by total households). The new distribution of households by household size is estimated by first distributing the future year households by size in the same proportions as in the base year. It is then assumed that all households capable of making the implied change (households of two or more for household size reductions; all households for household size increases) will have the same probability of changing in size by one. This probability of changing is set equal to the extent needed to match the forecast change in household size, and the resulting distribution of households by household size is used for the future scenario.

Household Income: The future year distribution of households by income quartile is estimated by assuming the proportional distribution of households by income quartile remains constant within each TAZ.

Resident Workers per Household: The change in the number of resident workers at the town level is obtained from combining base year and future year estimates of over-age-15 population and labor force participation by gender and age cohort. Dividing the base year and future year estimates of town-level resident workers by the base year and future year number of households in the town, respectively, produces estimates of the base year and future year average workers per household. All of the TAZs within each town are assumed to have the proportional change in workers per household implied by these base year and future year town-level estimates.

Household Workers: The future year TAZ number of households within each category of worker per household is estimated by using worker-per-household distribution curves developed by CTPS from the 1990 U.S. Census. These curves, summarized in Exhibit 4, indicate a default percentage distribution of households for the base year and future year TAZ estimates of average worker per household. The proportional changes in the default number of households within each category of worker per household implied by this comparison are applied to the actual base year TAZ distribution of households to obtain the distribution of households by workers per household to be used for the future scenario.

K-12 Employment: The level of employment in schools providing Kindergarten – 12th grade education is assumed to be proportional to the number of town residents of ages 5-19.

College Employment: The level of employment at all colleges within the region is assumed to be proportional to the number of regional residents of ages 20-24.

Dorm Population: The dorm population within a TAZ is assumed to be proportional to the total group quarters population within a TAZ.

Logan Person Trips: Base year Logan passenger trips are factored up by projected passenger growth rates to the future year. Base year Logan employee trips are factored up by projected Logan work force growth rates to the future year.

External Person Trips: Base year external person trips are factored up by population and employment growth rates implied in the forecasts of the neighboring regional planning agencies to the future year.

Attraction and Production Terminal Times: The attraction and production terminal times are estimated through the application of a model developed at CTPS. This model estimates terminal times as a function of household and employment density. Alternative estimates of the production and attraction terminal times for each TAZ are based on the household density ranges and employment density ranges. The larger of each pair of estimates are assigned to the TAZ. A few TAZs (locations of major generators such as airport or large colleges) were assigned terminal times in the base year different from the terminal time model estimates. In these cases, the model is used to estimate changes in the terminal times.

Estimation of Detailed Socioeconomic Characteristics

A three-way distribution of the households within each TAZ by household size, income, and workers is required in order to estimate the distribution of households by vehicle ownership levels. While this is available from the US Census at the regional level, such distributions at the TAZ level must be estimated through iterative proportional fitting techniques. Using the regional matrix as a seed, the cell values are adjusted through ten iterations to match row and column totals to the estimated ring-level totals to produce the three-way distribution of households for each geographical ring. Using these ring-level matrices as seeds, this process is then repeated for each TAZ within each ring.

Estimation of Vehicle Ownership

Household auto ownership is an input to trip generation and mode choice. It is forecast using a logit model developed with the 1991 Household Travel Survey and 1990 U.S. Census data. The model is integrated with the trip production procedures. The distribution of households by vehicle ownership estimated through the application of a set of models developed at CTPS. These models estimate the probability of a household owning a certain number of vehicles as a function of income, household size, workers per household, household density, employment density, household location, and transit walk access factors.

Estimation of Trip Productions and Attractions

The number of trip productions and trip attractions within a TAZ is estimated through the application of a set of models developed at CTPS. These models estimate the number of rip productions and attractions as a function of household size, workers per household, vehicles per household, income, household location, households, basic employment, retail employment, college employment, school employment, and service employment.

Balancing of Trip Productions and Attractions

Connecting a trip production with a trip attraction of the same trip purpose forms a trip. As a result, the number of productions and attractions for each trip purpose must be equal. In order to achieve this, the trip productions and attractions are balanced. The normal balancing procedure is to set the total number of regional attractions equal to the difference between the grand total of productions and the total number of external attractions. While that procedure was used to balance trip productions and attractions in 1995, the procedure required modifications for future year scenarios.

The large difference between regional employment and the number of resident workers and the large increase in external employment forecasted by the neighboring regional planning agencies and states produced home-based work trip volumes which seemed to be too high. In order to restrict trip volumes to plausible levels, the following changes were made in the balancing procedure:

- Regional home-based work trip productions are adjusted so that the increase from the base year total to the future year total is proportional to the forecast change in regional resident workers.
- Regional home-based work attractions were reduced by 3%, as was required to balance home-based work productions and attractions in 1990.
- External home-based work productions were set equal to the difference between the grand total of home-based work attractions and the regional home-based work productions.

Elimination of Logan Trip Productions and Attractions

While the total number of trip productions and attractions are equal, they include trips produced and attracted to Logan Airport. Since a separate model is used to estimate travel patterns to and from Logan Airport, Logan trips have to be purged from the trip matrices. The trips produced by or attracted to the Logan TAZs are thus eliminated, and Logan Airport passenger and employee survey data are used to identify the productions and attractions of other TAZs, which correspond to the Logan TAZ productions and attractions.

All of the Logan-related trips are eliminated from the original balanced estimates of trip productions and attractions, and files are produced which present estimates of the productions and attractions within each TAZ for home-based work, home-based personal business, home-based social and recreational, home-based school, home-based pick-up and drop-off, non-home-based work, and non-home-based other travel.

Preparation of Files for Other Components of Regional Model Set

In addition to trip productions and attractions, the results of the trip generation model also include several files used as inputs to other components of the regional model set.

Trip Distribution Model

The trip distribution model is the second step in the CTPS Regional Travel Forecasting Model Set. The trip distribution model links trip productions with trip attractions in the region to create matrixes of intra-regional and a portion of interregional travel.

Distribution of Internal-Internal Trips

The procedure developed relies on the implementation of a three-dimensional trip balancing strategy, as provided by the EMME/2 transportation planning software. Three dimensional trip balancing distributes production and attraction, which constitute the first and second dimensions respectively, subject to a third constraint on the distributed trips which is a combination of the scaled composite impedances and the total number of trips between districts. The 1991 transportation demand survey was used to define this third dimension constraint.

When applying the transportation demand model to generate trip demand forecasts, the object of a trip distribution model is the estimation of trip matrices based on future productions and attractions (P's & A's) given new transportation supply conditions, which translate into new composite impedance. A transportation demand survey exists only for the "base case", and therefore cannot be integrated in the procedure for evaluation of future scenarios. Thus, the object of the three-dimensional balancing procedure is broader than the generation of a trip matrix, which is the direct result of the balancing of productions and attractions. This step generates intermediate results useful for the calibration of a two-dimensional balancing for future year studies. The multipliers associated with the third dimension of this procedure were used to estimate "gamma" functions. Such functions of scaled composite impedances then allow for the creation of seed matrices of the trip distribution procedure (two-dimensional) to apply in scenario studies. These gamma functions translate the "reaction" of the three-dimensional procedure to the third dimension constraint and therefore, account for this constraint when applied to define a seed matrix.

The inputs of the procedure are:

- matrices of trip utilities, which are an output of the mode choice procedure;
- split factor matrices, which provide the total number of trips between district pairs for the peak and off-peak periods;
- trip-ends (production and attraction);
- household survey trip data.

Methodology

The procedure developed to distribute internal-internal trips relies on gamma functions derived from a three-dimensional balancing procedure and does not involve “friction factors” or “K factors.” The gamma functions transform scaled composite impedances into seed values for the two-dimensional balancing. This procedure involved three steps:

- three-dimensional balancing, in which geographical information is combined with scaled composite impedance values to define the third constraint;
- estimation of gamma functions;
- two-dimensional balancing for future years productions and attractions, using the gamma functions to compute seed values.

A three-dimensional balancing model was calibrated first with the 1991 data (productions, attractions and household survey results) on 12 combinations of six trip purposes and of two time periods. The six purposes considered are: home-based work, “wk”; non home-based work, “nw”; non home-based other, “nbo”; school, “sc”; socio-recreational, “sr”; and shopping, “sh”. The two periods considered are: peak, “pk”; and off-peak, “op.” The “peak” context includes the AM and PM peak periods while the “off-peak” context regroups the mid-day and evening periods.

The mode choice model generates sets of 4 utility matrices, one for each of four periods considered in the mode choice model (AM, PM, MD and NT). The AM and PM utilities are combined to compute PK composite impedances and the MD and NT utilities are combined to compute OP composite impedances. Although 6 purposes are considered in this procedure, only 5 sets of utility matrices are used as input to the procedure, since the same utilities are applied to the shopping and socio-recreational purposes. There are 12 split factor matrices, corresponding to each purpose and period combination of the trip distribution procedure. These matrices provide the respective shares of AM and PM trips for the PK periods, and the shares of MD and NT trips for the OP periods. As a result, we get 12 pairs of productions and attractions (P’s and A’s) corresponding to each purpose and period combination of the trip distribution procedure are developed.

The result of this effort leads to the estimation of some 60-gamma functions for the different combinations of period, purpose and interchange category. Gamma functions were then applied to compute the seed matrices of a two-dimensional balancing model for year 1991. Results of the two-dimensional balancing were compared to those obtained with the three-dimensional balancing. This comparison confirmed that the gamma functions used to generate seed values of the two-dimensional balancing were efficient in implicitly applying the third dimension constraint of the three-dimensional balancing procedure. Then, the two-dimensional balancing strategy was applied to distribute the productions and attractions for the future year.

Internal-External Trip Distribution

Internal-external trip distribution refers to a process in which all internal and external, that is, all 1083 traffic analysis zone AWDT trips ends, are distributed using AWDT highway impedances, but only the trips with one end in an internal zone and other end in an external zone are retained. The term "internal-internal" distribution refers to a redistribution of the internal zone trip ends that the internal-external distribution matched with other internal zone trip ends. The trip ends are split into peak period trip ends and off-peak period trip ends. These trip ends are then distributed separately using mode choice derived log sums of disutilities, appropriately calculated to reflect either the peak period (combining AM and PM peak log-sums) or the off-peak period (combining midday and night log-sums).

At the core of the internal-external trip distribution is the EMME/2-based three-dimensional balancing strategy, the third dimension incorporating the functions of constraining "k factors" and "f factors" which were carried over from our model set developed in UTPS software. This three dimensional balancing strategy performs a balancing of a seed matrix to zonal productions, zonal attractions, and subclass totals representing characteristics of the O-D trips of a transportation system, in this case, trip lengths as captured by highway impedances.

The basic output of the internal-external trip distribution model for the base year is an OD trip matrix, resulting from the third dimensional trip distribution as well as third dimension constraint and gamma functions. The base year inputs required for internal-external trip distribution include:

- Production and attractions matrixes by seven trip purposes output from the trip generation model: home-based work (wk); non home-based work (nw); non home-based other (nbo); school (sc); social-recreational (sr); shopping (sh); and pick-up and drop-off (pudo).

- The internal-external survey trip tables by purpose, which could only be coded at the 300 zone "land use' level: one zone for each of twenty-three Boston and five Cambridge neighborhoods; one zone for each of the remaining towns; and one zone for each of the ninety-seven externals.

- The AWDT 1083-zone highway skims files, one for time in minutes and another for tolls in cents (from UTPS files). [Note: It was determined that a peak, off-peak factor split was unnecessary given their similarity within each trip purpose.
- Production and attraction terminal times. The terminal times were modeled (in UTPS) but then were modified at major external zones during the development of the UTPS internal-external distribution model. These elements were used to create AWDT highway impedances.

The core of future year forecasting is the two-dimensional balancing strategy. It consists of preparing a seed matrix, through application of the relevant gamma functions on scaled highway impedance values, and using the resulting seed matrix within a two-dimensional balancing procedure. For the future year, inputs required for internal-external trip distribution and pudo trip distribution include:

- Production and attractions matrixes by seven trip purposes output from the trip generation model: hone-based work (wk); non home-based work (nw); non home-based other (nbo); school (sc); social-recreational (sr); shopping (sh); and pick-up and drop-off (pudo).
- Production and attraction terminal times
- Nine gamma functions for each of six internal-external trip purposes computed from base year three dimensional balancing.
- Nine gamma functions for internal-external pudo trips computed from k and f factors derived from UTPS AGM module.
- Split factor matrices for allocating internal-external trips to four time periods based upon the 1991 external travel survey and the household survey
- SOV/HOV occupancy rates by time periods to allocate internal-external trips and internal-internal pudo trips.

Mode Choice Model

Mode choice models by trip purpose were developed using 1991 Household Travel Survey data, travel impedances obtained from highway and transit networks, 1990 and 2000 U.S. Census data and other data sources. There were not enough survey records for each chosen mode to estimate separate model parameters for home-based shopping/personal business and home-based social/recreational trips. Therefore, these two purposes were combined into one, and four mode choice models were developed. These were 1) home-based work and work related (HBW); 2) home-based other (HBO), which include home-based shopping, personal business, social, recreation and other miscellaneous purposes; 3) home-based school (HBSC) and 4) non home-based (NHB) trips. The available travel modes were: 1) walk-access transit, 2) drive-access transit 3) single-occupancy vehicles 4) high-occupancy vehicles (2 persons only for HBW trips) 5) high-occupancy vehicles with 3 or more persons (HBW trips only) and 6) walk. Specific transit mode selection, i.e. local bus, express bus, light rail, commuter rail, occurs during the transit assignment process.

Mode choice deals with intra-regional trips only. Trips to and from external areas are dealt with separately and assumed to be only auto trips. Mode choice results in a split of both inter-zonal and intra-zonal trips; however, intra-zonal are only split between the walk and auto modes (SOV, HOV/HOV2, and HOV3). The transit modes do not capture intra-zonal trips. The mode choice model variables are defined as follows:

Tree coefficient: This represents the combined utilities of the drive-access and walk-access components of the transit nest.

In-vehicle time: Time spent in a transit vehicle during the trip. For the shared-ride modes, in-vehicle and out-of-vehicle time are functions of drive alone time.

Out-of-vehicle time: Includes all walk and wait time and drive-access time, unless the last is specified separately.

Drive-access time: Time, by automobile, to drive from a trip origin to a transit station.

Terminal time: The time spent getting in a vehicle at the production end and entering the modeled highway network and the time spent leaving the modeled network and parking the vehicle and walking at the attraction end of the trip. These times are as high as five minutes in the Boston CBD and as low as one minute in suburban areas. They are assumed to remain constant in the future.

Fare: Transit fare, in dollars, including one-half of any park-and-ride charges (because fare per one-way trip is used). The adult cash fare is used because that is what is coded within the transit network. 2004 Fare policy is assumed to be in place in the future.

Auto cost: Auto operating cost in dollars, which is computed using 9.8 cents per mile (1991 dollars) and toll costs, if any. Also, one-half any applicable parking costs (because costs per one-way trip are used). Parking costs are computed at the district level based on the average parking costs reported by auto mode users in the 1991 House Hold travel survey. For shared ride modes, total costs are divided by the appropriate auto occupancy.

They are assumed to remain constant over time.

Household size: Persons per household. For 2025, population and household forecasts are provided by MAPC.

Vehicles/person: Total vehicles per person in the household. Vehicles are forecast for 2025 using the vehicle availability model described earlier.

Population density: Total population per acre.

Percent transit origins/destinations: The transit share of work trip ends in the TAZ, as computed by the home-based work mode choice model.
Work dummy: Equal to one, if the trip is work-related. Zero otherwise.

Input Data: The input files include: impedance matrices for each mode, the person trip tables to be split, pre-determined coefficients for utility equations and socioeconomic characteristics by TAZ.

Home Based Work Model

Home-based work (HBW) mode choice is the only trip purpose that distinguishes between two person carpools (HOV2) and three or more person carpools (HOV3). Formerly, travel on HOV lanes was restricted to HOV3 vehicles during peak hours. For the past several years, any 2-person vehicle may also use these facilities.

A transit nest is incorporated into the model on the basis that the decision to take transit over the other modes is done before selection of a particular transit mode. The transit coefficients are generic for both walk access (WAT) and drive access (DAT) and include a coefficient for in-vehicle, initial wait, transfer wait and total walk time. Drive access time and production terminal times are included in drive access transit as one parameter.

The HBW model utilizes two transit impedances that are exclusive to this trip purpose model, the WAT transfers and DAT transfers. Survey data indicate that the number of transfers is critical to mode selection for work trips. The WAT fare includes the transit fare in dollars. For DAT, fare includes the transit fare, any parking cost and the drive access cost, with the latter being computed as 9.8 cents per mile. Population density by traffic zone, in people per acre, is included in walk access transit, and is positively correlated so that the greater the density, the more likely a traveler is to choose this mode. The zones with high population densities also have more transit stops. Vehicles per worker is a socioeconomic input unique to this trip purpose for DAT. It is also positively correlated, since a higher vehicle per worker ratio increases the likelihood of taking a vehicle to a park-and-ride lot.

The auto times and costs are generic for the three auto modes. For HOV2, the auto cost is divided by 2 and for HOV3, it is divided by 3.66 to reflect splitting the cost between the vehicle occupants. Household size is included as a positively correlated variable for the shared-ride modes and has a somewhat greater impact for HOV3 than HOV2.

Home Based Other Model

The home-based other (HBO) mode choice model combines the home-based shopping and home-based recreational trip tables output from the trip distribution process into a single HBO trip table that is split. The model is similar to the HBW mode choice model, except for the following four differences. First, since there is only one shared ride mode, household size is only a parameter for shared ride two plus. Second, the vehicles per person in a household is used, as opposed to vehicles per worker. Third, the number of transfers in the transit modes was not found to be a significant variable and therefore was not included. Finally, a distance dummy equal to one if the trip distance was less than a mile, zero otherwise, was added to the walk mode. This reflects the fact that people taking short trips for this purpose are more likely to walk than choose another mode.

Home Based School

The home-based school (HBSC) model does not have separate utility equations for WAT and DAT, as there were not enough DAT trips for this purpose to develop a valid model. Therefore, one transit utility equation was developed and applied for splitting both WAT and DAT trips. The HBSC model has a non-motorized nest, meaning that people first choose whether they are going to walk or take a motorized mode. Following that decision, the secondary decision is whether to drive alone, carpool or take transit. The equation for transit contains in-vehicle travel time and one out-of-vehicle travel time made up of initial wait, transfer wait and walk time. If the transit path is a drive access path, auto access time and production terminal time are included in total out-of-vehicle time. The fare variable includes the transit fare, parking cost (if any), and auto access cost (if applicable).

Non Home Based Model

The non home-based (NHB) model splits work trips and non-work trips. There is a work dummy variable in the two auto modes which is equal to one if the trip is a non home-based work trip and zero otherwise. The coefficient is positive for SOV and negative for HOV. The percent of trips attracted to the origin and destination zones, which are SOV, is a variable in the drive alone mode. The percentage is taken from Journey-to-Work data and is positively correlated. Finally, the distance dummy in the walk mode is equal to one if the distance is less than a mile. It has a positive coefficient.

Pre Assignment Procedure (after Mode Choice)

The completion of the runs for the 16 mode choice applications (4 trip purposes by 4 time periods) results in the creation of 68-person trip tables. To prepare for subsequent highway and transit assignments, the trip tables must be converted from production-attraction to origin-destination formats (except for NHB trips where they are the same). For the highway assignment it is necessary to convert person trips to vehicle trips by applying vehicle occupancy factors for HOV modes. These occupancy factors vary by trip purpose and, in the case of HBW trips a higher occupancy factor is applied to HOV3 trips. Their values are the following:

- home-based work trips HOV3 = 3.373
- home-based other trips HOV = 2.404
- home-based school trips HOV = 2.788

- non home-based trips HOV = 2.385

In addition to the manipulation of the output matrices from mode choice, it is necessary to bring in vehicle tables produced outside of the mode choice process. These include:

Trucks – The truck trip tables that have been used up to the present are based on 1963 survey data factored to the present.

External Through – This matrix includes trips that pass through the study area without stopping and hence are exogenous to the travel model. The trips were estimated from the 1991 external travel survey and have been factored since that time based upon production and attraction growth.

Taxi – The taxi vehicle trip table was originally developed from a 1993 survey and has been since revised several times based upon a factoring process. However, there has been no update of travel pattern data to create a true update trip table.

Logan Airport SOV & HOV – This trip table is developed from a separate modeling procedure, described in another section of the traffic model documentation.

Drive Access Transit Auto Access – DAT trips are determined through the mode choice process. Each DAT trip requires a vehicle access trip, with the total vehicle trips being slightly lower than the DAT total, as a small percentage of transit users carpool to park-and-ride-lots.

Internal-External SOV & HOV – The internal-external trip tables are generated through the trip distribution process.

Pickup/Drop-off SOV & HOV – The pickup/drop-off (PUDO) tables are those trips in which a person is dropped off at their destination (not an intermediate park-and-ride lot) by the driver. They are produced in the trip generation process along with other productions and attractions, then put through trip distribution.

Highway Assignment Model

The coding of the EMME/2 highway network basically follows the hierarchy of the functional classification system. Expressways, other than through denser urban areas, are generally coded for 60 mph speeds and hourly capacity per lane of 1950. Higher level arterials are coded for speeds ranging from 45 to 50 mph and corresponding capacities of 1050 to 1100. Lower level arterials and major collectors range from 35 mph to 40 mph, with capacities of 950 and 1000. Minor collectors and local streets that are not in urban centers range from 23 mph to 30 mph, with capacity generally at 800. Streets in urban centers can have substantially lower speeds and capacities.

The highway assignment utilizes the BPR function, which is a traditional procedure for planning models. This curve was based on the 1965 Highway Capacity Manual, which was parabolic in shape, and speed was fairly sensitive to increasing flows. The BPR curve is as follows:

Congested Speed = (Free-Flow Speed)/(1+0.15[volume/capacity]4)

For each time period the function is adjusted for apportioning the amount of demand to the number of hours. In the AM and PM peak periods, travel volume is apportioned to 3- hour periods, for the midday it is 6 hours and for the night it is 12 hours.

The highway assignment follows a straightforward procedure consisting of an equilibrium auto assignment. A multi-class assignment with generalized cost is applied. Generalized cost is computed as the combination of the travel time plus a fixed link cost. The multi-class assignment runs an assignment for the demand matrices of two modes, single occupancy vehicles and high occupancy vehicles from the vehicle trip tables for each class that are assigned by time period. Link tolls are contained in an extra attribute (@toll), which has average tolls along links where they are collected. A weight factor of five is applied to @toll to convert the cost in dollars to a time cost. This factor is based on an assumed value of time of $12.

The additional options assignment is then applied in order to compute output impedance matrices, including travel time, travel distance and tolls matrices. The travel time matrix output matrix is an optional output each time the assignment is run, but only one other impedance matrix per assignment can be produced. To output both the distance and toll matrices, the highway assignment must be run a second time. There is no vehicle occupancy factor to adjust the trip table, since this was already done when converting auto person trips to vehicle trips in the post-mode choice procedure. The additional demand to be assigned for additional volumes then is the same demand matrix applied to Class 1 – the SOV trip table. There are four attribute options available for the attribute matrix that is calculated. Additional path attribute is selected, which gives the average value of the path attribute for all the paths used in the assignment. The module then prompts the next class to be assigned, which is the HOV vehicle trip table. The HOV matrix for the particular time period is then specified. Since output impedance matrices are not calculated based on this demand, the prompt for the matrix to hold travel costs is bypassed. For the present model, the HOV is the final class for assignment, so the prompt for class 3 is bypassed.

The default number of iterations is 15; however the standard number used for assigning the CTPS regional model is 30. The model then asks for the stopping criteria for the relative gap. The relative gap is an estimate of the difference between the current assignment and a perfect equilibrium assignment, in which all paths used for a given O-D pair would have exactly the same time. The default is .5%, but .01% is selected, which should enable the full number of iterations to be carried out.

The other stopping criteria are the normalized gap (or trip time differential), which is the difference between the mean trip time of the current assignment and the mean minimal trip time. The mean trip time is the average trip time on the paths used in the previous iteration; the mean minimal trip time is the average trip time computed using the shortest paths of the current iteration. Again, a minimum level is selected, .01 minutes, in order for the designated number of iterations to be carried out. Note that the relative gap always decreases from one iteration to the next, whereas the trip time difference does not necessarily have this property. In a perfect equilibrium assignment, both the relative gap and the normalized gap are zero.

Transit Supply Model (Pre Trip Distribution)

The transit supply model is integral to the forecast of transit demand and the performance of different scenarios of infrastructure investment. Inter-zonal travel impedances faced by those trip makers who walk to their transit access points are the product of the transit system skimming process. This process contributes the transit portion of impedance to drive access transit skims as well. For this purpose the park and ride lots are regarded as special intermediate origin and destination zones.

The real network of commuter trains, ferries, rapid transit trains, local and express busses are represented digitally by an interconnected topology of infrastructure links. These links represent roadway and railway segments. Each link has a start node and an end node defined geographically with x-y coordinates. Each link also has a defined length and description as to which transit modes may traverse the link. In the case of commuter rail and rapid transit modes a link travel time in minutes is also defined. In our representation of the network, busses may traverse all highway links, but commuter rail and rapid rail transit use exclusive links only. They also use exclusive nodes. There is always a walk link between busses and trains. The transit network building conventions are explained below:

Transit Links and Lines: Bus lines are overlaid on highway links and rail links are coded separately. Sequences of transit links are defined together as lines. Each line is represented for each time period of the day with its own headway (frequency of service) and points of boarding and alighting. Each instance of a transit line traversing a transit link is a transit segment. Segments of the two rail modes take their travel time from the time of the link. Segments of the bus modes have transit times based on the scheduled line times apportioned by distance. Thus highway congestion doesn't directly affect bus travel times in the model. But if needed, bus speeds can be made a function of highway travel speeds. Future-year bus speeds are estimated on the basis of future-year congested highway speeds. The speeds of the various modes are determined on the basis of level-of-service data provided by the client and their consultants.

Walk-access Links: Walk-access times coded onto walk links represent the average walk time from all points in a zone to the transit node. These times were initially measured using the Arc/Info Geographic Information System (GIS) and then input to the EMME/2 transit network. Walking speed was assumed to be three miles per hour. The maximum walking distance used to connect a station to TAZ, regardless of mode is a mile.

Drive-access Path: A travel time is calculated from each internal TAZ to a PNR node. In order to calculate travel times, PNR nodes are considered TAZ's. Each park-and- ride node is connected to its associated transit node by a walk link. In the Boston core, no drive-access links are provided. The parking lot fare is coded directly on the link connecting the park-and-ride node to the station node. In cases where more than one parking lot serves a station, an average of their parking fee is coded.

Transfer Links: Transfer links are provided in the network where appropriate. For all downtown and some other rail stations, actual walking times from line to line were recently measured and these values are coded onto the transfer links.

Fare Coding Conventions: Fares were coded in the EMME/2 network at the appropriate transit nodes. Adult cash fares are used. Each mode is assigned a boarding fare and up to seven fare link codes. Because of the complexity of the area's fare system, not all private express bus, Green Line and Red Line (Braintree branch) fares are represented exactly as they occur. Park-and-ride parking charges are coded onto the walk link that connects the park-and-ride node to the transit station node.

Fares are given the value of $12 per hour or 1 minute for every 20 cents of fare. Boarding fares are imposed at transit nodes to represent local bus fares and rapid rail transit fares. Special coding procedures are followed at free transfer points. There, a penalty is imposed on walk access links instead. On commuter rail and express bus lines there are also fare penalties imposed on each segment traversed. Although fares are expressed in minutes to allow them to be impedances that influences path selection, they are not just lumped in with travel time.

Finally, each component of travel impedance is skimmed from the inter-zonal travel path separately and stored in its own inter-zonal matrix. Walk time is computed as link distance at three miles per hour. In the path selection process, the walk time is considered as twice the weight of in-vehicle travel time. Wait time is stored separately for the initial boarding and subsequent (transfer) boardings. The wait time is also factored in accordance with the characteristics of the transit mode being boarded. Each of these components of walk access transit impedance by time of day is input to the computation of drive access transit impedance and to the mode split process. They also become an element of the composite impedance upon which trip distribution is based.

Transit Assignment Model (post demand model)

After demand matrices of walk access and drive access transit trips have been forecast, these trips are assigned using our transit assignment model.
Drive access and walk access trips are combined by time period. The transit network and other parameters are the same for assignment as for the impedance skimming process.

Currently, congestion of passengers at stops and terminals does not influence travel times
or behavior in the model.

Path Building Conventions

The transit assignment implemented in EMME/2 is a multi-path assignment, based on the computation of optimal strategies. The optimal strategy is one that minimizes the total expected perceived travel time. The values shown in Table 2 are currently being used in estimating the perceived travel times between a given origin and destination. These values apply both to walk-access transit and drive-access transit and to all sub-modes. They relate to in-vehicle time. For example, a transfer wait time factor of 2.45 implies that travelers perceive a minute of such time as 2.45 times more onerous than a minute spent riding in a transit vehicle. Although these values are theoretically supposed to correspond to marginal rates of substitution implicit in mode choice model coefficients, their final values are also based on what is needed to find reasonable paths through the network within the path-builder.

Finally, summaries of transit boardings by mode and time of day are produced along with boardings and alightings at stations for rapid rail transit and commuter rail, with subtotals by line. For busses, summaries of boardings by MBTA bus route number and time of day are produced.

II. TRAVEL MODEL CHANGES DUE TO FTA GUIDANCE

In preparing the Silver Line ridership forecasts in 2003 the FTA identified a number of modifications CTPS needed in order to make to the regional travel demand model calculate user benefits. These modifications were designed to allow CTPS's model to produce New Starts User Benefits consistent with FTA standards and the SUMMIT software. The modifications fell into three categories, FTA required changes, model input updates based on newer information, and model calibration adjustments.

The FTA changes included revisions to the path/skim/assignment parameters, development of new mode choice model coefficients and a standardization of the catchment areas for all transit stops to one mile, regardless of mode. CTPS took it upon itself to standardize transfer link lengths.

Path/Skim/Assignment Parameters

Previously, the network processing procedures used by CTPS weighted walk time by a factor of 2.0 as compared with in-vehicle time. Wait time was adjusted by a factor of 1.0 (i.e., it was un-weighted). Additionally, initial and transfer wait times were determined by multiplying the headway by the following mode-specific factors:

- Rapid transit and commuter rail south side = 0.3

- Commuter rail north side= 0.5
- Local and Express Bus = 0.9

Where free transfers were necessary, boarding fares were coded on walk access links in terms of equivalent minutes.

Ideally, wait time should be weighted by the same amount implied in the mode choice model. However, the EMME/2 optimal strategies path builder does not necessarily result in a path that is truly consistent with the mode choice model. This discrepancy meant that the wait time weight factor had to be reset to 2.0, the same as the walk time weight factor.

Several SUMMIT runs conducted by CTPS last year indicated that the different treatment of rapid transit, commuter rail, and bus headways with regards to transfer and wait time factors were causing problems leading to illogical User Benefit results. These parameters were originally used by CTPS to reflect the fact that passenger arrivals at rail services tend to be schedule-driven whereby customers consult a timetable and hence do not arrive at random intervals. On the other hand, buses tend to operate on frequent headways resulting in random passenger arrivals, giving an average wait time of one-half of a bus's headway.

To accommodate these characteristics and also to allow for consistent treatment of frequent rail service or infrequent bus service, we amended these procedures so that wait time is a function of headway and not mode. The following procedure has been used successfully in the New York and New Jersey transit forecasting models:

- Wait time=0.5*headway where: headway<15 minutes
- Wait time=7.5+0.25*(headway-15) where: 15 min.<headway<30 min.
- Wait time=12.25+0.125*(headway-30) where: headway>30 min.

This function is continuous and monotonically increasing, an important characteristics for consistent SUMMIT results.

This was attributed, at least in part, to the absence of a transfer penalty in the path builder parameters. A transfer penalty of 2.45 minutes was added to the model, which was the ratio of the original transfer coefficient in the HBW mode choice model to the adjusted transit in-vehicle travel time coefficient in the HBW mode choice model. When the bus ridership continued to be overestimated, a bus boarding penalty of 5 minutes was added to the model, reflecting the preference exhibited by riders for rail over bus (consistent with modal bias coefficients in mode choice models with separate bus and rail modes). To reflect an apparent sub-modal bias and allow for calibration of the local buses in the assignment procedures, a seven-minute penalty is now assigned for each bus boarding.

The resulting path choice parameters are as consistent with the mode choice model as possible.

Dropped all non-logit decision rules: Following FTA's order, all non-logit decision rules (such as capping wait times or ratios of out-of-vehicle/in-vehicle time ratios) have been eliminated from the model.

Mode Choice Model Coefficients

Mode choice coefficients for the CTPS mode choice model were re-specified to conform to FTA guidance for application with SUMMIT. In particular:

- In-Vehicle Travel Time (IVTT) coefficients are now consistent (at the top nest level) among modes or the differences are readily explainable
- Out-of-Vehicle Travel Time (OVTT) to IVTT ratios are now generally between three-to-one and two-to-one.
- Walk coefficients are now consistent between the walk-to-transit and walk-only modes

This has required some modification of the CTPS estimation results. The following sections describe the strategy used for adapting each model to conform to these requirements.

Home-Based Work

The home-based work model was adjusted as follows:

- The existing tree (nest) coefficient for transit of 0.6791 was retained.
- A generic IVTT coefficient was established as the average of the estimated coefficient for auto and transit (equivalent top nest value). The resulting coefficient is equal to -0.05466 at the top nest level.
- The existing terminal time coefficient is used. This yields a ratio of 5.4 to 1 with IVTT. Given that this variable acts principally as a CBD flag (there is no other similar flag), this variable was kept as is although production-end terminal time will be added to drive access transit for improved mode-to-mode consistency.
- The walk time coefficient is now based on the estimated walk time coefficient for the walk mode and applied in the revised model for both the walk mode and the walk-to-transit mode. This value (-0.1007 at the top level) has a ratio of 1.8 to1 with IVTT.
- The initial wait time coefficient is now based on the original initial wait time variable, adjusted to account for the change in wait time for buses described above (it was 0.9 times the headway but is now 0.5 times the headway). As such, the coefficient is factored upward by 1.8 as compared to the estimated model. The impact of headway on the utility function is unchanged for the predominant bus mode. The ratio of wait time to IVTT is now 2.07 to 1.

- The transfer wait coefficient was set to the same coefficient value as initial wait.
- The auto access time coefficient was set to 2.5 times in-vehicle time. This is higher than the originally estimated model, but is much less than the implied relationship incorporated in the station-choice model.
- The number of transfers coefficient was originally maintained at the same level as in the estimated model. The ratio to in-vehicle time declined to 2.45 minutes per transfer due to the increase in the transit in-vehicle time coefficient. Since the transfer time coefficient also increased substantially, any further increase in transfer penalty was hard to substantiate. However, when the bus-boarding penalty was adopted, the transfer variable was dropped and replaced by a boarding time variable. The IVTT coefficient was applied to the boarding time variable.
- The original cost coefficients were retained which are approximately equal to -0.32 for all modes (at the top level). This resulted in a $10.32 per hour value of time of which is generally consistent with other models in the Northeast.
- Various socioeconomic coefficient values were retained.

Table 2 in Appendix A presents the revised coefficient values.

Home-Based Other

- The existing tree (nest) coefficient of 0.3722 for transit was retained.
- A generic IVTT coefficient was established as the average of the estimated coefficient for auto and transit (top nest equivalent value). The resulting coefficient is equal to -0.01965 at the top nest level. This value is just below the FTA guidance of -0.02 to -0.03 and is also less than the HBW coefficient, which is reasonable.
- The existing terminal time coefficient, which yields a ratio of 11.74 to 1 with IVTT, was retained. Given that this variable acts principally as a CBD flag (there is no other similar flag) this variable was retained in its present form. The production-end terminal time will be added to drive access transit for improved mode-to-mode consistency.
- The walk time coefficient was originally based on the estimated walk time coefficient for the walk mode and applied in the revised model for both the walk mode and walk-to-transit mode. This value (-0.08239 at the top level) had a ratio of 4.19 to 1 with IVTT, so it was lowered to -.0589 (three times the in-vehicle travel time coefficient).
- The initial wait time coefficient was based on the original initial wait time variable, adjusted to account for the change in wait time for buses described above (it was 0.9 times the headway and is now 0.5 times the headway). As such, the coefficient was factored upward by 1.8, as compared with the estimated model. The impact of headway on the utility function is unchanged for the predominant bus mode. The ratio of wait time to IVTT was thus 4.23. The initial wait time coefficient was lowered to -.0589 (three times the in-vehicle travel time coefficient).

- The transfer wait coefficient was set equal to the initial wait coefficient.
- The auto access time coefficient was set to 2.5 times the coefficient for IVTT.
- The number of transfers coefficient was maintained at the same level as in the Home-Based Work model (2.45 minutes per transfer). This accounts for the significant reduction in the value of the transfer time coefficient. However, this variable was replaced by the boarding time variable (including a 2.45-minute penalty per transfer) which has the same coefficient as the IVTT variable.
- The original cost coefficient was defined as the average (at the top nest level) of the transit and automobile cost coefficients. This resulted in a value of time of $5.27 per hour, which is approximately half of the HBW value of time.
- Various socioeconomic coefficient values were retained.

The revised coefficient values are presented in Appendix A, Table 3.

Home-Based School

The nesting structure of the Home-Based School model (which lumps transit and drive access trips together in a motorized nest and walk trips in a separate non-motorized nest) was difficult to reconcile with the SUMMIT software's expectation of a transit v. non-transit nesting structure. Fully researching the best way to integrate the Home-Based School model structure with SUMMIT would be a very time consuming exercise. As there are relatively few Home-based School trips CTPS decided it was best to drop the Home-Based School trips from the User Benefit analyses altogether. This was accomplished by manually setting the build scenario trips and utilities equal to the baseline trips and utilities within SUMMIT.

Non-Home Based

- The existing multinomial structure was retained.
- A generic IVTT coefficient was established as the average of the estimated coefficient for auto and transit. The resulting value was -0.03022.
- The existing terminal time coefficient, which yields a ratio of 10.58 to 1 with IVTT, was retained. Given that this variable acts principally as a CBD flag (there is no other similar flag), this variable was retained in its present form. The production-end terminal time will be added to drive access transit for improved mode-to-mode consistency.
- The walk time coefficient is now based on the estimated walk time coefficient for the walk mode and applied in the revised model for both the walk mode and walk-to-transit mode. This value (-0.07525 at the top level) has a ratio of 2.49 to 1 with IVTT.
- The initial wait coefficient is now based on the initial wait coefficient from the alternate CTPS non-home based model (-0.08333). The ratio of wait time to in-vehicle time is now 2.75 to 1.
- The transfer wait coefficient was set equal to the initial wait coefficient.
- The auto access time coefficient was set to 2.5 times the IVTT coefficient.

- The number of transfers coefficient was originally maintained at the same level as in the Home-Based Work model (2.45 minutes per transfer). This accounted for the significant reduction in the value of the transfer time coefficient. However, this variable was replaced by a boarding time variable (including a penalty of 2.45 minutes per transfer) which was set equal to the IVTT coefficient.
- The cost coefficients were set to equal the automobile cost coefficient. This resulted in a value of time of $9.87 per hour, which is approximately equal to the HBW value of time.
- Various socioeconomic coefficient values were retained.

Table 4 in Appendix A presents the recommended coefficient values.

Dropped parking supply constraints

Following FTA's direction, PNR supply constraints have been eliminated from the model.

III. AIR QUALITY MODELING

Nearly all of the air quality impacts of alternative transportation scenarios can be estimated using the outputs of the travel model in combination with emissions factors produced by running EPA's MOBILE emissions model. The amount of air pollution emitted by highway traffic depends on prevailing highway speeds and vehicle miles traveled on the region's network.

The model set estimates future traffic volumes, average highway speeds, and vehicle miles for every roadway link in the modeled network. The MOBILE model procedures emissions rates by pollutant by year by vehicle speed. Thus, after the model set is run for a given scenario and for a given pollutant, an emission factor that corresponds to the modeled speed on a given roadway link is selected and multiplied by the vehicle-miles on that link. This yields an estimate of emissions on that one link. The emissions from al 40,000 or so links are likewise calculated and then summed to obtain an estimate of regional emissions for that particular pollutant.

Typically, we estimate three major pollutants emitted by autos, trucks, and transit: Carbon Monoxide (CO), Volatile Organic Compounds (VOC) and Nitrous Oxides (Nox). Four components make up traffic-generated pollution. One of these is handled by the model, while the remaining three are dealt with off-model.

For any given build of project scenario, emissions changes compared to the no-build scenario are due to mode shifts from auto to transit, resulting in fewer vehicles on the roadway network, hence lower vehicle-miles traveled and lower total emissions. In addition, the reduced number of vehicles on the roadway network is sometimes sufficient to lessen congestion and therefore raise modeled speeds slightly, and in the range of typical urban driving speeds, this can lead, in and of itself, to mode emissions reductions. Hence, the more auto diversions there are, the greater the emissions improvements, all else being equal.

A small fraction of the emissions associated with each scenario is estimated through separate procedures, not connected to the travel model, and then added to the emissions obtained by the procedure just described. These manual, supplemental procedures are used for estimating commuter rail diesel locomotive and MBTA bus emissions. Essentially, emissions factors appropriate for each of these modes are applied to estimates of future locomotive and bus miles, respectively, to obtain total emissions associated with each mode.

IV. SUMMIT ANALYSIS

Background

The Federal Transit Administration (FTA) distributed the SUMMIT software tool in 2002 for the purpose of calculating User Benefits. The FTA in order to compare New Starts submissions from around the country decided to use User Benefit measure in the selection of projects to receive federal funding. The concept of User Benefits is based on consumer surplus, which reflects the difference in price or cost of travel for all modes and for all users in the transportation system, between two alternatives.

User Benefits are equal to all changes in times and costs for all modes—with the costs translated into equivalent time units so that they can be rolled in with actual time—that are associated with the provision of a particular transit service.

Travel forecasting models consider many variables in the process of determining how trips are made from one location to another. Variables such as time, transfers, and costs are all used by the mode-choice model to split person trips into transit, auto, and non-motorized modes. The regional travel demand model supplies this information to SUMMIT, which in turn converts them all into units of time.

Concept of Utility

User Benefits represent changes in the generalized cost of travel for individual travelers. For each proposed transit capital improvement project, cumulative or total User Benefits are calculated for a no-build or TSM alternative and a build alternative. These costs are collectively known in the mode-choice model as the utility of travel and this is calculated for each mode, namely auto, non-motorized, and transit. The following generalized costs are input into the mode choice model and are captured in the User Benefit calculation:

Auto Utility

- Tolls for autos
- Costs associated with parking
- Operating costs associated with an auto such as gas and insurance
- Travel times reflecting congestion on the roadways due to traffic

Transit Utility

- In-vehicle time: The accumulated travel time on board a transit vehicle
- Dwell time: The cumulative time riders spend in a vehicle while people board and alight
- Walking time to and from the station
- Driving time to and from a park-and-ride lot
- The time it takes to transfer to another mode or to another line in the same mode
- The time a person spends waiting for a transit vehicle
- Park-and-ride lot fees
- Number of transfers
- Transit fares

Costs are converted to time using a deflation factor and the assumption that the value of time is $12/hour.

Inputs

The Travel Demand Model data is broken down into time of day and purpose. This information is supplied for a no-build and build alternative. The time periods used are AM, Midday, PM, & Nighttime, and collectively they represent an average weekday. The purposes consist of Home-Based-Work, Home-Based-Other, and Non-Home Based. The CTPS regional travel demand model provides the following data as inputs into the SUMMIT User Benefit calculation.

- Total person trips
- Transit mode shares
- Auto utility
- Transit utility
- Access factors by market segment
- In-vehicle travel time coefficient for auto
- In-vehicle travel time coefficient for transit

Total person trips are all trips by purpose and time period that use one of three modes of travel in the regional transportation system.

Transit shares are the output of the mode choice model and represent the percentage of people who take transit from one location to another.Transit shares and the person trips are used to calculate the number of transit and auto trips, which are used in the calculation.

Auto and transit utilities were described earlier.

Access factors by market segments are how SUMMIT stratifies markets of person trips based on the type of access they have to the transit system.

- Can-walk represents the percentage of trips with respect to zone pairs that can walk to transit and then walk from transit to their destination.
- Must-drive represents the percentage of trips in a traffic zone that have access to transit via an automobile and cannot walk to transit.
- No-transit represents the percentage of all person trips not covered by the other two market segments.

The User Benefit calculation also includes the in-vehicle travel time coefficient used in the mode choice model for the auto and transit modes that were developed from travel survey data.

Application of User Benefits

A key purpose of implementing a new transit project is to improve the service and benefits provided to transit customers. There are many ways to express those benefits that may extend beyond the transit project itself and include such things as reduced congestion on area roadways and associated improvements in air quality. For its calculation of cost effectiveness, FTA has developed a standardized methodology for expressing benefits in terms of hours of User Benefits. These benefits, which come directly from the regional travel demand-forecasting model, encompass both hours of travel time saved by riders on the Red/Blue Connector and travel-time savings for transit riders using other MBTA services.

APPENDIX A

TABLE 2
Home-Based Work Mode Choice Model Specification

		Impedance Variables									Socio-Economic Variables		
Home-Based Work	Nest Coeff	IVTT	Terminal Time	Walk Time	Initial Wait	Transfer Wait	Auto Access	Boarding Time	Fare ($)	Auto Cost ($)	Population. Density	Vehicles/ Worker	HHld Size
Drive Alone													
Top Level	1	-0.05466	-0.292							-0.32			
Application Level		-0.05466	-0.292							-0.32			
Ratio to IVTT/VOT ($/hr)		1	5.34211							$ 10.25			
SR2													
Top Level	1	-0.05466	-0.292							-0.32			0.07322
Application Level		-0.05466	-0.292							-0.32			0.07322
Ratio to IVTT/VOT ($/hr)		1	5.34211							$ 10.25			-1.33955
SR3+													
Top Level	1	-0.05466	-0.292							-0.32			0.2168
Application Level		-0.05466	-0.292							-0.32			0.2168
Ratio to IVTT/VOT ($/hr)		1	5.34211							$ 10.25			-3.96634
Walk													
Top Level	1			-0.1007									
Application Level				-0.1007									
Ratio to IVTT/VOT ($/hr)													
Walk-Transit													
Top Level	0.6791	-0.05466		-0.1007	-0.11292	-0.11292		-0.05466	-0.32		0.01889		
Application Level		-0.08049		-0.14828	-0.16628	-0.16628		-0.08049	-0.47121		0.02781		
Ratio to IVTT/VOT ($/hr)		1		1.8423	2.06593	2.06593		1	$ 10.25		-0.34551		
Drive-Transit													
Top Level	0.6791	-0.05466	-0.292	-0.1007	-0.11292	-0.11292	-0.13665	-0.05466	-0.32	-0.32		0.2897	
Application Level		-0.08049	-0.42998	-0.14828	-0.16628	-0.16628	-0.20122	-0.08049	-0.47121	-0.47121		0.4266	
Ratio to IVTT/VOT ($/hr)		1	5.34211	1.8423	2.06593	2.06593	2.5	1	$ 10.25	$ 10.25		-5.30011	

APPENDIX A

TABLE 3
Home-Based Other Mode Choice Model Specification

		Impedance Variables									Socio-Economic Variables			
Home-Based Other	Nest Coefficient	IVTT	Terminal Time	Walk Time	Initial Wait	Transfer Wait	Auto Access	Boarding Time	Fare ($)	Auto Cost ($)	Population. Density	Vehicles/ Worker	HHld Size	Distance Dummy
Drive Alone														
Top Level	1	-0.01965	-0.2308							-0.22378				
Application Level		-0.01965	-0.2308							-0.22378				
Ratio to IVTT/VOT ($/hr)		1	11.7463							$ 5.27				
SR2+														
Top Level	1	-0.01965	-0.2308							-0.22378			0.1976	
Application Level		-0.01965	-0.2308							-0.22378			0.1976	
Ratio to IVTT/VOT ($/hr)		1	11.7463							$ 5.27			-10.0566	
Walk														
Top Level	1			-0.05895										0.9005
Application Level				-0.05895										0.9005
Ratio to IVTT/VOT ($/hr)														-15.2757
Walk-Transit														
Top Level	0.3722	-0.01965		-0.05895	-0.05895	-0.05895		-0.01965	-0.22378		0.00883			
Application Level		-0.05279		-0.15838	-0.15838	-0.15838		-0.05279	-0.60123		0.02373			
Ratio to IVTT/VOT ($/hr)		1		3.0002	3.0002	3.0002		1	$ 5.27		-0.44951			
Drive-Transit														
Top Level	0.3722	-0.01965	-0.2308	-0.05895	-0.05895	-0.05895	-0.04912	-0.01965	-0.22378	-0.22378		0.71239		
Application Level		-0.05279	-0.6201	-0.15838	-0.15838	-0.15838	-0.13198	-0.05279	-0.60123	-0.60123		1.914		
Ratio to IVTT/VOT ($/hr)		1	11.7463	3.0002	3.0002	3.0002	2.5	1	$ 5.27	$ 5.27		-36.2564		

APPENDIX A

TABLE 4
Non-home Based Work Mode Choice Model Specification

		Impedance Variables									Socio-Economic Variables		
Non-Home-Based	Nest Coefficient	IVTT	Terminal Time	Walk Time	Initial Wait	Transfer Wait	Auto Access	Boarding Time	Fare ($)	Auto Cost ($)	Work Dummy	Distance Dummy	Percent SOV
Drive Alone													
Top Level	1	-0.03022	-0.3197							-0.1817	0.1926		0.00885
Application Level		-0.03022	-0.3197							-0.1817	0.1926		0.00885
Ratio to IVTT/VOT ($/hr)		1	10.5791							$ 9.98	-6.37326		-0.29295
SR2+													
Top Level	1	-0.03022	-0.3197							-0.1817	-0.7627		
Application Level		-0.03022	-0.3197							-0.1817	-0.7627		
Ratio to IVTT/VOT ($/hr)		1	10.5791							$ 9.98	25.2383		
Walk													
Top Level	1			-0.07525								0.493	
Application Level				-0.07525								0.493	
Ratio to IVTT/VOT ($/hr)												-6.5515	
Walk-Transit													
Top Level	1	-0.03022		-0.07525	-0.08333	-0.08333		-0.03022	-0.1817				
Application Level		-0.03022		-0.07525	-0.08333	-0.08333		-0.03022	-0.1817				
Ratio to IVTT/VOT ($/hr)		1		2.49007	2.75745	2.75745		1	$ 9.98				
Drive-Transit													
Top Level	1	-0.03022	-0.3197	-0.07525	-0.08333	-0.08333	-0.07555	-0.03022	-0.1817	-0.1817			
Application Level		-0.03022	-0.3197	-0.07525	-0.08333	-0.08333	-0.07555	-0.03022	-0.1817	-0.1817			
Ratio to IVTT/VOT ($/hr)		1	10.5791	2.49007	2.75745	2.75745	2.5	1	$ 9.98	$ 9.98			

SIP Key Transit Project Comparisons

							Emissions using MOBILE		
Project	Change in Linked Transit Trips	Auto Person Trips Switching to Transit	Change in Unlinked Transit Trips	User Benefits (hours)	Change in VMT	Change in VHT	Change in CO (kg)	Change in VOC (kg)	Change in NOx (kg)
Silver Line Phase III	16,300	8,200	69,900	18,400	-58,000	-4,100	-750	-80	-96
Silver Line Phase IV	11,700	8,700	32,900	11,100	-47,000	-2,600	-660	-61	-85
Urban Ring Phase I	14,800	14,800	20,400	5,400	-81,500	-4600	-1,100	-109	-137
Urban Ring Phase II	16,200	11,200	34,400	9,200	-94400	-5600	-1,200	-133	-159
Urban Ring Phase III	48,600	39,000	117,000	44,000	-290,200	-17,400	-3900	-429	-499
Fairmont CRR Improvements	300	200	400	800	-1,100	-60	-15	-1	-2
Arborway Restoration	200	100	200	200	-500	-30	-7	-1	0
Blue Line to Lynn	2,000	2,000	4,000	2,900	-12,900	-800	-175	-17	-22
Red / Blue Connector	3,100	1,400	-7,300	3,800	-9,700	-500	-123	-14	-18
Fitchburg CRR Station at Union Sq.	500	300	700	400	-1,600	-100	-20	-2	-3
Added Parking Capacity (1000 spaces)	2,000	2,000	2,700	na	-11,900	-500	-166	-16	-21
Green Line to W. Medford	16,300	11,900	14,800	10,100	-70,400	-4,000	-1,084	-83	-117
Green Line to W. Medford & Union Sq	17,600	14,500	15,000	11,800	-80,300	-5,100	-1,016	-83	-114

11/10/05

Transit Project Prioritization

Project	Goal 1 Rating	Goal 2 Rating	Goal 3 Rating	Goal 4 Rating	Goal 5 Rating	Goal 6 Rating	Goal 7 Rating	Rating Sum
Urban Ring Phase 3	3	3	3	3	1	3	2	18
Silver Line Phase III	3	3	3	2	1	3	2	17
Urban Ring Phase 2	3	2	3	2	1	3	2	16
Green Line to West Medford & Union Square	2	2	3	2	1	3	3	16
Fairmount Line Improvements	2	1	3	1	3	3	3	16
Green Line to West Medford	2	2	3	2	1	3	3	16
Urban Ring Phase 1	2	2	3	2	1	3	3	16
Silver Line South Extension to Ashmont and Mattapan	2	2	2	2	1	3	3	15
New Commuter Rail Station at Union Square	2	1	3	1	1	3	3	14
Blue Line: Wonderland to Lynn	2	2	2	2	1	3	2	14
Red Line/Blue Line Connector	2	2	2	1	1	3	2	13
Arborway Restoration	2	1	2	1	1	3	2	12

Goal #1: Improve Mobility

Project	Service to Areas With Unmet Demand	Service During Time Periods With Unmet Demand	Service to Underserved Employment Centers	Reliability	Intercon-nectivity	Minimize Transfers	Total	Goal Rating
Arborway Restoration	2	1	1	2	3	3	12	2
Red Line/Blue Line Connector	3	1	1	1	3	3	12	2
Green Line to West Medford	3	1	1	1	3	3	12	2
Green Line to West Medford & Union Square	3	1	1	1	3	3	12	2
Fairmount Line Improvements	3	1	1	1	1	3	10	2
Silver Line Phase III	3	1	3	1	3	3	14	3
Urban Ring Phase 1	2	1	2	1	2	3	11	2
Urban Ring Phase 2	2	1	3	2	3	3	14	3
Urban Ring Phase 3	2	1	3	3	3	3	15	3
Blue Line: Wonderland to Lynn	2	1	2	1	3	3	12	2
Silver Line South Extension to Ashmont and Mattapan	2	1	1	2	3	3	12	2
New Commuter Rail Station at Union Square	1	1	1	1	3	3	10	2

Goal #2: Utilization

Project	User benefits (hours)	Goal Rating
Arborway Restoration	58,600	1
Red Line/Blue Line Connector	1,113,400	2
Green Line to West Medford	2,431,900	2
Green Line to West Medford & Union Square	2,519,800	2
Fairmount Line Improvements	234,400	1
Silver Line Phase III	6,533,900	3
Urban Ring Phase 1	1,582,200	2
Urban Ring Phase 2	2,695,600	2
Urban Ring Phase 3	11,456,300	3
Blue Line: Wonderland to Lynn	1,084,100	2
Silver Line South Extension to Ashmont and Mattapan	3,252,300	2
New Commuter Rail Station at Union Square	117,200	1

Goal #3: Cost-Effectiveness

Project	Farebox Recovery	Rating	Cost per Unit Benefit	Rating	Total	Goal Rating	Capital Cost (2005 $)	Operating Costs/Day (2005 $)	Annualized Costs (2005 $)	Revenue (2005 $)	User benefits (hours)
Arborway Restoration	21.75%	2	$141	1	3	2	$94,980,000	$9,638	$8,278,453	$1,800,237	58,600
Red Line/Blue Line Connector	6.47%	1	$14	3	4	2	$263,714,976	$2,786	$15,960,951	$1,032,405	1,113,400
Green Line to West Medford	28.40%	3	$10	3	6	3	$336,400,000	$15,959	$23,994,621	$6,813,360	2,431,900
Green Line to West Medford & Union Square	16.93%	2	$13	3	5	3	$459,114,286	$23,693	$33,308,139	$5,638,477	2,519,800
Fairmount Line Improvements	38.41%	3	$18	3	6	3	$66,990,076	$1,007	$4,142,149	$1,591,002	234,400
Silver Line Phase III	18.44%	2	$9	3	5	3	$741,638,168	$50,031	$57,249,871	$10,556,520	6,533,900
Urban Ring Phase 1	29.36%	3	$16	3	6	3	$111,272,142	$66,645	$25,916,999	$7,608,548	1,582,200
Urban Ring Phase 2	14.31%	2	$20	3	5	3	$658,368,903	$50,540	$52,616,847	$7,527,707	2,695,600
Urban Ring Phase 3	12.08%	2	$21	3	5	3	$3,115,619,968	$195,601	$236,234,515	$28,532,054	11,456,300
Blue Line: Wonderland to Lynn	3.91%	1	$40	2	3	2	$712,099,237	$10,102	$43,854,114	$1,713,791	1,084,100
Silver Line South Extension to Ashmont and Mattapan	5.90%	1	$2	3	4	2	$48,783,037	$16,945	$7,766,503	$458,551	3,252,300
New Commuter Rail Station at Union Square	36.69%	3	$6	3	6	3	$10,000,000	$252	$648,042	$237,767	117,200

Goal #4: Air Quality/Climate

Project	CO Decrease (2005 kg)	CO Decrease Rating	VOC Decrease (2005 kg)	VOC Decrease Rating	NOx Decrease (2005 kg)	NOx Decrease Rating	Total	Goal Rating
Arborway Restoration	7	1	1	1	0	1	3	1
Red Line/Blue Line Connector	123	2	14	1	18	1	4	1
Green Line to West Medford	411	2	42	2	13	1	5	2
Green Line to West Medford & Union Square	365	2	47	2	17	1	5	2
Fairmount Line Improvements	15	1	1	1	2	1	3	1
Silver Line Phase III	510	2	40	2	80	2	6	2
Urban Ring Phase 1	1,100	2	109	2	137	2	6	2
Urban Ring Phase 2	1,100	2	109	2	137	2	6	2
Urban Ring Phase 3	2,800	3	315	3	396	3	9	3
Blue Line: Wonderland to Lynn	289	2	29	2	43	2	6	2
Silver Line South Extension to Ashmont and Mattapan	660	2	61	2	85	2	6	2
New Commuter Rail Station at Union Square	20	1	2	1	3	1	3	1

Goal #5: Service Quality

Project	Safety/ Security	Comfort/ Convenience	Customer Information	Total	Goal Rating
Arborway Restoration	1	1	1	3	1
Red Line/Blue Line Connector	1	1	1	3	1
Green Line to West Medford	1	1	1	3	1
Green Line to West Medford & Union Square	1	1	1	3	1
Fairmount Line Improvements	2	3	2	7	3
Silver Line Phase III	1	1	1	3	1
Urban Ring Phase 1	1	2	1	4	1
Urban Ring Phase 2	1	1	1	3	1
Urban Ring Phase 3	1	1	1	3	1
Blue Line: Wonderland to Lynn	1	1	1	3	1
Silver Line South Extension to Ashmont and Mattapan	1	1	2	4	1
New Commuter Rail Station at Union Square	1	1	1	3	1

Goal #6: Land Use and Economic Development

Project	Serves Existing Urbanized Area	Brownfield/ Infill Development	Population/ Employment Served	Existing Land Use Character	Local Plans That Support TOD and Sustainable Land Use	Total	Goal Rating
Arborway Restoration	3	2	2	3	3	13	3
Red Line/Blue Line Connector	3	N/A	2	3	3	*11*	*3*
Green Line to West Medford	3	2	3	3	2	13	3
Green Line to West Medford & Union Square	3	2	3	3	2	13	3
Fairmount Line Improvements	3	2	2	3	2	12	3
Silver Line Phase III	3	2	2	3	3	13	3
Urban Ring Phase 1	3	N/A	3	3	N/A	*9*	*3*
Urban Ring Phase 2	3	3	3	3	3	15	3
Urban Ring Phase 3	3	3	3	3	3	15	3
Blue Line: Wonderland to Lynn	3	2	1	3	3	12	3
Silver Line South Extension to Ashmont and Mattapan	3	2	2	3	2	12	3
New Commuter Rail Station at Union Square	3	2	2	3	2	12	3

Goal #7: Environmental Justice

Project	Serves Target Neighborhoods	Rectifies Barriers	Responds to EJ Issues in RTP	Avoids Burdens Without Benefits	Total	Goal Rating
Arborway Restoration	2	1	2	3	8	2
Red Line/Blue Line Connector	2	1	1	3	7	2
Green Line to West Medford	2	2	3	3	10	3
Green Line to West Medford & Union Square	2	2	3	3	10	3
Fairmount Line Improvements	3	3	3	3	12	3
Silver Line Phase III	2	2	2	3	9	2
Urban Ring Phase 1	3	1	3	3	10	3
Urban Ring Phase 2	3	1	2	3	9	2
Urban Ring Phase 3	3	1	2	3	9	2
Blue Line: Wonderland to Lynn	3	1	2	3	9	2
Silver Line South Extension to Ashmont and Mattapan	3	3	3	3	12	3
New Commuter Rail Station at Union Square	2	2	3	3	10	3

MEMORANDUM

TO: **Boston Region MPO Members** **June 16, 2005**

FROM: **Scott Peterson**

RE: **SIP Transit Modeling Assumptions**

BACKGROUND

Twelve transit projects were examined as part of the analysis done for the SIP Transit Project Prioritization work. The analysis involved a number of assumptions, which are described in this memo. The assumptions used to model the projects were about alignments (adding or modifying them), stations, headways, run times, parking lot access, and fares.

PROJECT DESCRIPTIONS

Each description below represents CTPS's best understanding of the project, as it would exist in 2025. Some projects are further along than others in the planning process and hence have better-defined service plans. For projects that are at an earlier stage in the planning process, CTPS has estimated the service plan to the best of its ability.

In the analysis each project described below was compared with a common no-build scenario. The no-build scenario is the 2025 transportation network described in the 2004–2025 Regional Transportation Plan, minus the project in question. Parking and crowding were not considered to be limiting factors in any of the analysis that was performed. If you need clarification on any of this, please contact either Karl Quackenbush or myself.

1. Red/Blue Connector

Alignment: The Blue Line was extended 0.4 miles from Bowdoin Station to Charles/MGH Station on the Red Line.

Service: There were no changes to the Red Line or Blue Line services.

Stations: A new station was added to the Blue Line at Charles/MGH.

Fares: The fare assumed at Charles St. was the existing $1.25. A free transfer between the Red and Blue Lines was provided.

Transfers: The new Blue Line station at Charles/MGH provided a transfer between the Blue Line and the Red Line.

Other Changes: None.

2. Arborway Restoration

Alignment: The Green Line E branch was extended south along S. Huntington Ave., Centre St., and then South St., where it ended at Arborway at a location adjacent to the Orange Line's Forest Hills Station. In this extension the Green Line shared the right-of-way with traffic.

Service: The Green Line E branch currently travels between Lechmere and Heath Street with headways of 7 min. in the peak period, 9 min. in the midday, and 10 min. at night. These service frequencies were maintained to Arborway.

Stations: The Arborway Restoration added 8 new stops after Heath St.:

- VA Hospital
- Bynner St.
- Perkins St.
- Moraine St.
- Beaufort St.
- JP Center
- Monument St.
- Child St.
- Forest Hills

Fares: The current Green Line surface fare structure was used, which means a $1.25 boarding fare was collected on the inbound trains and nothing was collected on the outbound trains.

Transfers: The Green Line provides transfers in the Central Subway to the Red, Silver, and Blue Lines. Several of the new stations provided transfers to nearby bus stops.

Other Changes: The project eliminated the Route 39 bus that currently travels from Forest Hills to the Back Bay with headways of 5 min. in the peak, 10 min. in the midday, and 10 min. in the evening.

3. Green Line to West Medford

Alignment: The alignment for this extension started at Lechmere Station and headed northwest, meeting with the Lowell Line just south of Washington St. in Somerville. From there the alignment ran parallel to the Lowell Line to West Medford.

Service: This service operated on headways of 7 min. in the peak period, 9 min. in the midday, and 10 min. at night.

Stations: The Green Line to West Medford added 7 new stops after Lechmere:

- Washington St.
- Gilman Sq.
- Lowell St.
- Ball Sq.
- College Ave.
- Winthrop St.
- West Medford (High St.)

Fares: Fares at the stations added by this project were $1.25.

Transfers: The Green Line provides transfers in the Central Subway to the Red, Silver, and Blue Lines. Several of the new stations allowed for transfers to nearby bus stops.

Other Changes: None.

4. Enhanced Green Line to West Medford and Union Square

Alignment: The alignment for this extension consisted of two branches, both extending from Lechmere, with one going to West Medford and the other going to Union Square in Somerville. The West Medford Branch started at Lechmere Station and headed northwest, meeting with the Lowell Line just south of Washington St. in Somerville. From Washington St. the alignment ran parallel to the Lowell Line to West Medford. The Union Square Branch started at Lechmere Station and headed northwest along the Fitchburg commuter rail line to the Union Square area.

Service: The Green Line service to West Medford operated on headways of 5 min. in the peak period, 10 min. in the midday, and 10 min. at night. The Green Line service to Union Square operated on headways of 7 min. in the peak period, 9 min. in the midday, and 10 min. at night.

Stations: The Green Line–to–West Medford component of this project added 7 new stops after Lechmere:

- Washington St.
- Gilman Sq.
- Lowell St.
- Ball Sq.
- College Ave.
- Winthrop St.
- West Medford (High St.)

The Green Line–to–Union Square component would add one new stop at Union Square.

Fares: Fares at the stations added for this project were $1.25.

Transfers: The Green Line provides transfers in the Central Subway to the Red, Silver, and Blue Lines. Several of the new stations allowed for transfers to nearby bus stops.

Other Changes: None.

5. Fairmount Line Improvements

Alignment: The project's improvements to the Fairmount Line do not change its alignment. It is approximately 9.2 miles long, running from South Station to Readville. It passes through the communities of Dorchester, Roxbury, and Mattapan.

Service: The Fairmount commuter rail line service to Readville currently operates on headways of 25 min. in the peak periods, 60 min. in the midday, and 80 min. at night. The new service improved midday and nighttime headways to 40 min.

Stations: The project upgraded the existing Uphams Corner and Morton Street Stations and provided four new stations at:

- Newmarket
- Four Corners
- Talbot Ave.
- Blue Hill Ave.

Fares: The existing stations used the existing MBTA commuter rail zonal fare system; the new stations this project created were assumed to be in fare zones 1, 1a, and 1b.

Transfers: The Fairmount commuter rail line service provides transfers at South Station to the Red and Silver Lines. Several of the new stations allowed for transfers to nearby bus stops.

Other Changes: None.

6. **Silver Line Phase III**

Alignment: The Silver Line Phase III tunnel linked downtown and South Station via Boylston, Chinatown, and New England Medical Center Stations with Silver Line Phase I (Dudley Square to downtown) and Silver Line Phase II (South Station to the South Boston waterfront). Silver Line Phase I entered this new tunnel near New England Medical Center. A bus rapid transit route was added between Dalton Street in the Back Bay and Silver Line Way.

Service: The connection of Silver Line Phase I with Phase II increased the number of Silver Line routes from seven to nine. The headways in the tunnel section were less than 1 minute in the peak periods and less than 3 minutes in the off-peak periods. The surface routes of Silver Line Phase I and Phase II operated on existing schedules. The Dalton route operated on headways of 10 min. in the peak, 20 min. in the midday, and 25 min. at night.

Stations: Several new stations were added along the Dalton route to the Back Bay. New stations were also added at New England Medical Center, Chinatown, and Boylston.

Fares: Boarding fares for the new service were assumed to be $1.25. Also, free transfers between the new service and the Green, Red, and Blue Lines were assumed.

Transfers: The Silver Line Phase III service provided transfers to the Green Line at Boylston and transfers to the Red Line and to Silver Line Phase II at South Station. Several of the new stations along the Dalton route allowed for transfers to nearby bus routes.

Other Changes: None.

7. **Urban Ring Phase I**

Alignment: The proposed project, which is located in the municipalities of Boston, Chelsea, Everett, Medford, Somerville, Cambridge, and Brookline, was comprised of 12 bus routes along a circumferential corridor encircling downtown Boston, along with new and improved commuter rail stations connecting to the service.

Service: Improvements in Phase I include increased service frequency on the three existing limited-stop crosstown (CT) routes during peak hours, and nine new limited-stop CT routes connecting activity centers and regional transportation nodes. In addition, three new express commuter bus (EC) routes are implemented to increase one-seat rides for trips originating outside the project corridor. All of the CT routes were assumed to operate on headways of 10 min. in the peak, 20 min. in the midday, and 30 min. at night. The EC routes were assumed to operate during peak periods on headways of 12 min. in the peak direction and 20 min. in the off-peak direction. No off-peak-period service was provided.

Stations: Over a hundred new stops were added along these routes.

Fares: The new service was assumed to cost $1.25 to board and was assumed to allow free transfers to the Green Line, Red Line, and Blue Line.

Transfers: Transfers were allowed at various Green Line, Red Line, Orange Line, Blue Line, Silver Line, and commuter rail stations. Several of the new stations allowed transfers to nearby bus stops.

Other Changes: None.

8. **Urban Ring Phase II**

Alignment: The project, which is located in the municipalities of Boston, Chelsea, Everett, Medford, Somerville, Cambridge, and Brookline, is comprised of bus rapid transit (BRT) facilities along a circumferential corridor encircling downtown Boston and also includes new and improved commuter rail stations that connect to the BRT service. The BRT facilities provide a combination of exclusive busways and bus-only lanes. Where the service runs on the road in mixed traffic, signal priority for the buses is provided. The busways and bus-only lanes would be constructed primarily along active and inactive rail corridors and along transportation easements and corridors reserved for such purposes.

Service: The existing CT bus routes were modified into six CT routes and six BRT routes. The Urban Ring service was assumed to operate on headways of 10 min. in the peak periods and 15 min. in the off-peak periods.

Stations: Forty-three new BRT stations were added by this project. Three new commuter rail stations were added and five others underwent significant expansions. New or expanded commuter rail stations were added at downtown Chelsea, Sullivan Square, Gilman Square, Union Square, Yawkey, Ruggles, JFK/Umass, and Uphams Corner.

Fares: The new service was assumed to cost $1.25 to board and was assumed to allow free transfers to the Green Line, Red Line, and Blue Line.

Transfers: Transfers are allowed at various Green Line, Red Line, Orange Line, Blue Line, Silver Line, and commuter rail stations. Several of the new stations allow for transfers to nearby bus stops.

Other Changes: None.

9. Urban Ring Phase III

Alignment: In Phase III of the Urban Ring, light rail transit (LRT) service was added to the Urban Ring Phase I/II service between Assembly Square in Somerville and Dudley Square in Roxbury. This LRT passed through Sullivan Square, Lechmere, Kendall Square, MIT, Boston University, Longwood Medical Area, and Ruggles, and crossed the Charles River near the BU Bridge.

Service: The Urban Ring LRT service was assumed to operate on headways of 5 min. in the peak period, 15 min. in the midday, and 20 min. at night.

Stations: Forty-three new BRT and LRT stations were added by this project. Three new commuter rail stations were added and five others underwent significant expansions. New or expanded commuter rail stations were added at downtown Chelsea, Sullivan Square, Gilman Square, Union Square, Yawkey, Ruggles, JFK/Umass, and Uphams Corner.

Fares: The new service was assumed to cost $1.25 to board and was assumed to allow for free transfers to the Green Line, Red Line, and Blue Line.

Transfers: Transfers were provided at various Green Line, Red Line, Orange Line, Blue Line, Silver Line, and commuter rail stations. Several of the new stations allowed for transfers to nearby bus stops.

Other Changes: None.

10. Blue Line to Lynn

Alignment: This project extended the Blue Line five miles from Wonderland Station in Revere, north along the eastern shore commuter rail line, to Lynn.

Service: The current Blue Line service was used, with headways of 4 min. in the peak period, 9 min. in the midday, and 11 min. at night.

Stations: One new station was added to the Blue Line in Lynn; the new station was adjacent to the Lynn commuter rail station.

Fares: The cost to board at this new station was assumed to be $1.25.

Transfers: The new Lynn Blue Line station allowed for a transfer to the adjacent Lynn commuter rail station.

Other Changes: None.

11. Silver Line Phase IV

Alignment: This project extended Silver Line bus rapid transit service beyond Dudley Station to Ashmont and Mattapan. Service followed Warren Street from Dudley to Grove Hall and then split into two branches. One branch, 4.4 miles in length (including the segment between Dudley and Grove Hall), continued on Blue Hill Ave. to Mattapan Station, and the other, 3.5 miles in length, continued along Washington St. to Ashmont. These branches replaced the existing MBTA bus routes 23 and 28.

Service: It was assumed that the Silver Line Phase IV routes would have the same headways as the routes 23 and 28 buses but would have reduced run times. These new routes would feed into the Silver Line New England Medical Center (NEMC) tunnel entrance and turn around at Silver Line Way.

Stations: Instead of stations every eighth of a mile, the new service provided stops about every quarter mile. Several of the new stations allowed for transfers to nearby bus stops.

Fares: It was assumed that the new service would cost $1.25 to board.

Transfers: Several of the new stations provided for transfers to existing bus routes.

Other Changes: None.

12. New Commuter Rail Station at Union Square

Alignment: This project added a new commuter rail station on the Fitchburg commuter rail line near Union Square in Somerville, between the existing Porter Sq. Station in Cambridge and North Station in Boston.

Service: No changes were made to the Fitchburg commuter rail line, but there was a slight increase in run time due to the new station.

Stations: One station was added at Union Square.

Fares: The new service, in accordance with the existing commuter rail zonal fare structure, was assumed to cost $1.25 to board.

Transfers: The new station allowed transfers to nearby bus stops.

Other Changes: None.